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September 1980

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IMPLICATIONS FOR ARMS CONTROL IN
TECHNOLOGY TRANSFER TO LESS DEVELOPED
COUNTRIES (LDC'S)

Considerations in Controlling
Dual-Use Technology Products:

An Overview

AC8WC122

Volume I

Prepared For

U.S. ARMS CONTROL & DISARMAMENT AGENCY

Prepared By

Science Applications, Inc.
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U.S. ARMS CONTROL & DISARMAMENT AGENCY

by

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The views and conclusions contained in this report are those of the authors and should not necessarily be interpreted as representing the official policies, either expressed or implied, of the Arms Control and Disarmament Agency or the U.S. Government

Volume I.

REPORT DOCUMENTATION PAGE		1. REPORT NO.	2. AD-A100894	3. Recipient's Accession No.
4. Title and Subtitle IMPLICATIONS FOR ARMS CONTROL IN TECHNOLOGY TRANSFER TO LESS DEVELOPED COUNTRIES (LDC'S) Considerations in Controlling Dual-Use Technology Products: An Overview.		5. Report Date September 1980		
7. Author(s) David E. Murphy and James O. Frankosky		8. Performing Organization Rept. No.		
9. Performing Organization Name and Address Science Applications, Inc. Center for Security & Policy Studies 1710 Goodridge Drive McLean, Virginia 22102		10. Project/Task/Work Unit No.		
12. Sponsoring Organization Name and Address U. S. Arms Control and Disarmament Agency WEC/TT 320 21st Street, NW Washington, DC 20451		11. Contract(C) or Grant(G) No. (C) AC8WC122, Vol. I (G)		
13. Type of Report & Period Covered Final 9/78-9/80		14.		
15. Supplementary Notes (4) Final rept. Sep 78-Sep 80				
16. Abstract (Limit: 200 words) This volume provides some insights into possible motivations and potential paths for LDS's to exploit dual-use technologies in achieving indigenous capabilities in potentially destabilizing systems such as surface-to-surface missiles, attack aircraft, tanks, and fast attack (Naval) craft/missiles.				
17. Document Analysis a. Descriptors Ballistic missiles, cruise missiles, attack aircraft, anti-ship missiles, combat vehicles, surface-to-surface missiles, inertial guidance b. Identifiers/Open-Ended Terms Dual-use technology, licensed coproduction, less developed countries, technology transfer, indigenous third world arms industries, arms transfers, conventional arms, Argentina, Brazil, Egypt, India, Israel, S. Korea, N. Korea, S. Africa, Taiwan, Yugoslavia c. COSATI Field/Group Aircraft, combat vehicles, missiles, navigation and guidance, surface launched missiles				
18. Availability Statement Release unlimited		19. Security Class (This Report) UNCLASSIFIED		21. No. of Pages 67
		20. Security Class (This Page) Unclassified		22. Price

412417

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ACKNOWLEDGEMENTS:

Recognition is hereby given to the technical contributions of Donald E. Farrar and Robert I. Widder, former SAI employees, to the content of this report as well as the overall guidance and understanding of Mr. Maurice Eisenstein as Technical Representative of the Arms Control & Disarmament Agency which were significant in the successful completion of this analytical research project.

SUMMARY:

This is one of a series of four volumes of technical reports which address the implications for arms control in technology transfer to less developed countries. The four volumes include:

- Volume I* - Considerations in Controlling Dual-Use Technology Products: An Overview (Unclassified)
- Volume II - Exploitation of Civil Inertial Navigation Systems (INS) for Military Purposes by Less Developed Countries (LDC'S) (Confidential)
- Volume III - A Study of the Exploitation of Dual-Use Technologies: South Korea (Confidential)
- Volume IV** - Essays on the Role of Coproduction and Dual-Use Technology in the Development of LDC Arms Industries (Unclassified)

This volume provides some insights into possible motivations and potential paths for LDC's to exploit dual-use technologies in achieving indigenous capabilities in potentially destabilizing systems such as surface-to-surface missiles, attack aircraft, tanks, and fast attack (Naval) craft/missiles.

- * This volume.
- ** Includes index to all four volumes.

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INTRODUCTION

At the present time LDCs in all parts of the world can obtain complete weapons systems from a continually growing number of capable and competing suppliers. Some LDCs acquire new systems through coproduction agreements with supplier nations while others design and produce indigenous systems although for various reasons some parts for most of these systems are still made abroad. A number of LDCs find it cost-effective to upgrade systems already in their inventories by purchasing modular components or entire retrofit packages from foreign suppliers, or by manufacturing such components under license. Thus, as long as military systems and components can be obtained freely, without constraints imposed on their use by the supplier, and if the LDC purchaser has reasonable assurances that delivery schedules will be adhered to and spare parts made available, most LDCs will continue to acquire a substantial portion of the weapons they need abroad. This does not imply any diminution of the determination on the part of LDCs to seek the maximum degree of independence they can in their arms acquisition programs. This determination is manifested by efforts to diversify suppliers, by insisting on coproduction arrangements rather than outright purchase of new systems, by seeking to maximize the technology transfer arising from coproduction agreements, by insisting on local manufacture of a percentage of subsystems or parts, and by themselves designing and producing military products even though they may still import key elements of the systems.

There is no suggestion that these attitudes will change,* indeed many foreign suppliers have shown themselves ready to accommodate to LDC preferences in their marketing practices as later described in pages 4-11.

This paper examines likely LDC reactions to a situation in which for whatever reason they are unable to conclude sales or coproduction agreements with foreign suppliers leading to the acquisition of new weapons systems or the modular components necessary to the upgrading of existing weapons. A first response would undoubtedly be to shift existing supplier-recipient relationships in an effort to find new suppliers. In these circumstances, it is appropriate to consider the extent to which the intensification of competition for arms sales among industrialized nations and certain advanced LDCs, both Communist and non-Communist, would facilitate the LDC quest for new suppliers. If LDCs failed in this, a second reaction might be for some LDCs to increase their efforts to produce the required systems indigenously assuming that the capability to do so is believed to exist. This would imply the ability to master the various critical dual-use technologies discussed in this series of studies and to do so without foreign assistance.

Because not all LDCs would be able or willing to exercise the option of indigenous production, are there other steps which could be taken which might alleviate the

* This viewpoint was recently expressed by the Israelis in explanation of the development of their own indigenous arms industry, and while it is certainly overstated (in view of their continuing dependence on the United States), it is probably a fair reflection of the attitudes one would encounter in other LDCs:

"Israel's defense and electronics industries were born out of necessity, the results of a series of embargos such as the one French General de Gaulle imposed after the 1967 Six Day War. Israel decided it would be virtual suicide to leave production of vital equipment in non-Israeli hands and moved full force towards setting up an ultra-sophisticated manufacturing capability, fast gearing itself to American standards as U.S. material replaced the French equipment in Israeli stockpiles." Special Israel Advertising Section, Aviation Week and Space Technology, October 8, 1979.

situation? Are there products not normally controlled to LDCs which embody dual-use technologies and which could be exploited by LDCs to upgrade weapons systems? This proposition will be preliminarily tested by examining four, potentially destabilizing weapons systems and drawing tentative conclusions regarding the degree to which civil products could be applied to their development or upgrading. The systems are:

- Surface-to-Surface Missiles
 - Ballistic Guided Missiles
 - Cruise Missiles
- Attack/Ground Support Aircraft-Fixed and Rotary Wing
- Tanks
- Fast Attack Craft/Missiles

A considerable portion of the material used in preparing this paper was developed in connection with related studies of ten LDCs: Argentina, Brazil, Egypt, India, Israel, Korea (North and South), South Africa, Taiwan and Yugoslavia.* Because of the special concerns of this paper, however, information on other LDCs will be included where appropriate and available.

NOTE: It should be emphasized that this paper reflects a broad overview of the technical considerations underlying possible exploitation by LDCs of dual-use technology products as one option in upgrading weapons systems. Not all of the technical judgments have been predicated on detailed analysis. A definitive statement would require more comprehensive treatment of the pertinent systems and the technical problems inherent in the application of them to civil products.

* See Volume IV of this series for summarizing results.

MILITARY SYSTEMS AND COMPONENT AVAILABILITY AS A FACTOR

Any consideration of LDC reactions to a situation in which they could no longer rely on foreign assistance in equipping their armed forces must be prefaced by an appreciation of the current state of the world's arms markets. World Military Expenditures and Arms Transfers 1968-1977* states that "world-military expenditures continued to rise in 1977" and that "worldwide arms exports increased by more than seven percent in 1977." The same study notes that "developing countries continue to receive the largest share of arms exports" and points out that there has been "a significant increase in the number of suppliers." The reasons for this can be found in the growing number of West European nations engaged in the arms trade, and the entry on the scene of LDCs as arms suppliers in their own right. It is not, however, the magnitude of the increase in arms transfers alone which will affect LDC responses to actions limiting their access to the arms market, but rather the diversity of that market and of the motivations for arms transfers demonstrated by supplier nations. By breaking down arms exporting states into several groups and examining their arms supply activities, it is possible to obtain insights into the reasons why LDCs find themselves increasingly in a "'buyers' market," able to play one supplier off against the other.

Nations in the NATO Integrated Military Structure

While sharing many U.S.-political military concerns, these nations have assumed growing importance in arms supply to developing countries. Not only do they look upon arms exports as a way to reduce unit production costs of weapons systems intended for their own forces, but exports have come to play an increasingly important role with regard to employment stability, balance of payments and the maintenance of favorable trade relations with the many LDCs

* World Military Expenditures and Arms Transfers 1968-1977, U.S. Arms Control and Disarmament Agency, October 1979. Unless otherwise noted, all figures in this section on arms exports are taken from this ACDA document.

on whom they rely for vital raw materials. The United Kingdom leads with 1977 exports of \$782 million, up from \$675 million in 1976. After the United States and the Soviet Union it offers to buyers the broadest and technically most sophisticated array of land, sea and air weapons systems and subsystems of any country in the world. The Federal Republic of Germany now ranks second to Great Britain. Its 1977 sales totaled \$758 million compared with \$650 million in 1976. In several critical areas the FRG rivals the United States as the dominant producer and supplier. Its propulsion systems for land and marine application are found all over the world, and it is a leading designer and builder of fast patrol boats as well as armored vehicles. Both the FRG and the United Kingdom participate in joint production ventures with France; this has increased their flexibility with regard to arms exports and has resulted in the rapid expansion of the FRG aircraft industry. Like the United Kingdom and other European suppliers, there is also developing in West Germany a growing military electronics industry which figures importantly in the design and sale of modular components for systems upgrade. Italy's arms exports for 1977 of \$303 million amount to less than half of those of the United Kingdom and FRG, yet this understates the role of Italy as a supplier to LDCs. Although Italy, in many ways, owes its growth as an arms producer to licensed production over the years of many U.S. systems, and to joint production with France (the OTOMAT anti-ship missile) and other European partners of several new systems, it has begun to design and market a variety of its own systems and subsystems. The OTO Melara 76 mm naval gun is an outstanding example of indigenous design. These weapons are found in the navies of many developed and developing countries. Italian electronics firms such as SELENIA also produce excellent fire control and electronic warfare systems. Elsewhere in NATO, Belgium ranks fourth in total sales with \$114 million in 1977. As in the past, these sales derive from Belgium's high quality infantry arms and other ordnance items. The Netherlands, with sales of \$38 million in 1977 and \$60 million in 1976, specializes in naval electronics. Firms such as Hollandse Signaalapparaten have built on the very advanced Dutch civilian electronics industry to design and market excellent naval fire control systems, radar, etc. They have been fitted on a number of LDC naval vessels including those of Brazil and India and are also sold to advanced countries such as the United

States. A newcomer to the group of key NATO arms exporters is Norway (sales of \$30 million in 1976) which is probably due to its development of the PENGUIN anti-ship missile and production of fire control systems for the fast patrol boats it manufactures. In sum, the members of the NATO Integrated Military Structure have developed impressive arms design and production capabilities. In the future, these countries, working together with France (see below) will probably expand cooperation in the design and production of military systems in order to negotiate with the U.S. on a more equal footing. This was the underlying theme of a symposium on armaments production held in Brussels on 15-17 October 1979 under the aegis of the Western European Union.* If such policies are pursued, and this seems likely, continued increases in arms exports to LDCs will probably result.

Other West European Nations

Although retaining its non-military ties to the North Atlantic Treaty Organization, France continues to pursue an independent policy with regard to arms transfers. As a result, its 1977 arms sales of \$1,232 million again put it in third place after the United States and the USSR. The French rationale for their arms transfer policies parallels that of their European neighbors (economy of scale in the production of arms for use by its own forces, domestic political concerns for unemployment particularly in high technology industries, and balance of payments problems brought on by the rise in oil prices). Beyond this, however, lie policy considerations which may explain the unusual intensity and aggressivity with which France markets its military wares. There is on the one hand, the basic French conviction that Europe must emulate France in developing an independent defense capability which implies the existence of a strong, innovative armaments industry. At the same time, France views the export of its high quality weapons systems, such as the anti-ship missile EXOCET, as reinforcing French prestige and influence throughout the world. For France to hold these views and act on them comes as no surprise but as France deepens its relationships with other European states in arms production ventures, French attitudes and readiness

* Aviation Week and Space Technology, October 29, 1979, pp. 64-65.

to export the products of joint ventures could mean an overall increase in arms transfers to the developing world. Sale of the Anglo-French JAGUAR to India is a case in point.

Three other non-NATO countries in Western Europe deserve attention in this overview of LDC weapons acquisition options. They are Spain, Sweden and Switzerland. The first, Spain, occupies a position today in arms production and transfers which resembles that of Italy several years ago. It produces a variety of weapons under license, all of them vintage by current European standards but adequate to the needs of many LDCs. Total sales in 1978 were \$38 million. As a formally neutral nation, Sweden produces a full line of modern weapons systems for its own forces and for export. For example, its BOFORS automatic gun has been sold to more than 20 countries. Its electronics industry has teamed with the Yugoslav firm ISKRA to coproduce laser range-finders which can be fitted to a variety of vintage tanks. Swedish sales in 1977 equalled \$47 million, up from \$40 million in 1976. Swedish officials have indicated that export sales now exceed sales to the Swedish armed forces and that some exports will account for about 80 percent of all defense contracts.* Tunisia is among the LDCs added to the list of Swedish customers; recently Sweden sold two of its SPICA class patrol boats to Malaysia. Switzerland, a neutral like Sweden, is also an important arms producer and supplier. In 1977 it sold a total of \$180 million in military systems, an increase of \$50 million over 1976. This places Switzerland just below Italy in the ranks of European arms suppliers. Again like Sweden, it produces a wide range of systems for its own forces and concentrates on high quality ordnance and electronics for export. For example, the anti-aircraft guns in both land and naval versions made by Oerlikon-Buehrle are sold or manufactured under license in several countries. The CONTRAVES firm produces a variety of radar and fire control systems, while MOWAG offers armored personnel carriers and other wheeled armored vehicles which are popular with developing countries. Considering West European arms suppliers as a whole, a pattern appears to be emerging whereby several of the more advanced nations will join together to design, develop and produce new weapons embodying technologies of the mid-to-late 1970s. As these systems come on line, pressures will arise to export them. Middle level countries

* International Defense Review, March 1979, p. 438.

such as Norway and the Netherlands, or the neutrals, will continue to specialize in selected but high quality systems with export a major consideration for development cost recuperation. Belgium, Spain, and to some extent Austria* and Portugal (both of the latter countries exported arms in 1977), will cover sectors of the arms trade of lesser interest to the others and often directed at the least developed countries. Taken together, however, sales of these latter suppliers in 1977 reached \$266 million so it is not a negligible amount. In light of the above, it seems inevitable that the rich variety of products and multiplicity of sources offered by competing West European arms suppliers will have the effect of widening the options for LDCs as buyers. Finally, we come to Japan. Its potential role in the production and export of arms is considered within the West European framework partly for editorial convenience but partly because many of the problems and motivations which have influenced some European states to expand their armaments industries are pertinent to Japan. These problems include special defense systems needs not always met by the United States, a desire to reap the technological benefits of advanced weapons systems production, concern for full employment in high technology industries for the future and the need to import vital raw materials, especially oil, from LDCs. As of 1977, Japan exported only \$19 million in arms, an insignificant amount for a country with its GNP when compared to the records of scores of other industrialized and even developing countries. However, this figure reflects an increase over the 1976 figure of \$10 million. For a while, any marked expansion of the Japanese armaments industry will probably be devoted to the needs of the Japanese defense forces. Over time, and despite the psychological problems arising from World War II, pressures may develop for arms exports and the nations of East Asia represent a natural market. That the Japanese understand how to design weapons systems which could meet the special needs of Asians can be seen in their main battle tanks, Type 61 and Type 74. These were developed to replace American tanks and to reflect the

* It is possible that Austrian arms exports in the amount of \$57 million may derive from other than weapons transfers. The Austrian firm, Steyr, produces specialized machinery for the manufacture of gun barrels using a patented process which greatly reduces the time normally required. These machines have been purchased by both the United States and the USSR. The Washington Post, November 9, 1979, p. A-18.

smaller stature of the tank crews as well as narrow roads, lighter bridges, etc.* Japan has also developed and begun testing on three new missile systems: an air-to-surface anti-shipping missile, an air-to-air missile and a man-portable surface-to-air missile.** This activity all involves the application of microelectronics in which Japan excels. It is still too early to determine whether Japan will apply its growing capacity to design and develop new weapons systems to the export market. If it does, the implications will extend well beyond the purview of this paper although clearly, LDCs will have been afforded another, important option in addition to those they already have.

Warsaw Pact Nations

The Soviet share of the arms market has not changed a great deal from 1968 (29.8%) to 1977 (29.5%). While Soviet decisions on arms transfers are normally linked to political objectives, both short and long term, with regard to recipient countries, the USSR has also come to realize that there is money to be made in the trade when arms transfers are put on a hard currency basis. According to World Military Expenditures and Arms Transfers 1968-77, 11 percent of Soviet hard currency earnings in 1977 came from arms sales. It is possible, of course, that in the future the Soviet Union would refrain from disturbing a situation in which one or more selected LDCs were denied access to arms. It might even participate in the denial process. If it did not, however, or if it believed it should respond to requests for arms from LDCs unable to obtain them elsewhere, it should be remembered that the USSR has the capability of initiating arms transfer actions on a scale more massive and with greater speed than any other country in the world. Soviet production of many systems (tanks, for example), exceeds that of the U.S. as do the numbers of weapons in reserve stocks and available for transfer abroad. Thus, possible Soviet actions would have to be taken into account in considering arms acquisition options open to LDCs. Of perhaps greater interest in considering Soviet opportunities to make arms available to

* Jane's Weapons Systems 1979-80, pp. 327-328.

** Aviation Week and Space Technology, November 5, 1979, p. 17.

selected LDCs in circumstances of the type we are examining, is the growth of arms production and sales on the part of other members of the Warsaw Pact. Total sales for 1977 are in excess of \$900 million dollars with Czechoslovakia and Poland leading with \$445 million and \$294 million respectively. Since a portion of this is accounted for by transfers within the Warsaw Pact, it is not possible to identify sales to hard currency areas, specifically to LDCs. But it seems evident that these countries have a respectable range of light aircraft, armored vehicles, ordnance and electronics to offer LDCs if the price were right or if the USSR desired that transfers be made for political reasons but wished itself to remain aloof. Cuba has been included in this group although not a formal member of the Warsaw Pact because it continues to register arms exports, even though it is not an arms producer. Since there was a drop from \$120 million in Cuban arms transfers in 1976 to \$9 million in 1977, it is possible that these figures reflect transfers by Cuba of Soviet made weapons to those African nations or liberation groups with which it is associated.

Other Communist Nations

Included under this heading are the Peoples Republic of China, North Korea and Yugoslavia. This group further expands LDC capabilities to obtain arms and while its members are not indifferent to the trade balance benefits (particularly Yugoslavia), their arms transfer activities to date have reflected political motivations. The PRC is not now a major arms supplier. Its peak transfers (\$588 million) occurred in 1972, following the last Indian-Pakistani conflict, and were down to \$85 million in 1977. Pakistan has been the major recipient of PRC arms assistance (tanks and aircraft were major items) which came at a time when other nations embargoed shipments to the subcontinent. While the PRC cannot rival either the Western industrial states or the Warsaw Pact in terms of weapons systems sophistication, it could make available for export arms of sufficiently high quality to make them attractive to many LDCs if they were cut off by other suppliers. North Korea, a country which maintains a precarious political balance between its Soviet and Chinese neighbors, has not generally been thought of as a serious arms exporter.

The volume of its arms transfers is not great (\$80 million in 1976 down to \$9 million in 1977) but it is noteworthy that the recipients of North Korean arms are all LDCs and include the smaller countries of Black Africa. In addition, because North Korean weapons systems are patterned after those of the USSR they are compatible with systems obtained by other countries directly or indirectly from the Soviet Union. This has also opened modest markets in the Middle East and North Africa where North Korean equipment has received good marks for its reliability and ruggedness. Finally, in this group of countries we have Yugoslavia, which leads the others in arms transfers and has placed considerable emphasis on arms exports both as a hard currency earner and to satisfy Yugoslav foreign policy objectives. In 1976 Yugoslavian arms transfers amounted to \$120 million; this grew to \$152 million in 1977. A large part of this consists of standard ordnance but increasingly Yugoslavia is seen as a major supplier of military electronics to Third World countries. Officials of the leading Yugoslav electronics firm, ISKRA, have stated that of the approximately \$20.4 million dollars in military electronics exported in 1978, the majority went to LDCs.* Behind this export emphasis on LDCs is the desire of Yugoslavia to underline and reinforce its position in the Non-aligned Movement. Whatever its motivation might be, it is a fact that Yugoslavia provides LDCs with an important alternative to other Western suppliers with particular regard to the kinds of modular electronic components which are essential to systems upgrade. For example, the TLMD-2 laser rangefinder can upgrade vintage Soviet tanks in the hands of many LDCs. The Yugoslavs also can provide a laser irradiation detector (LID) as an upgrade module for land or sea vehicles defense against laser rangefinders or illuminators.

Arms Transfers From LDCs

In considering alternatives which would be open to LDCs were they unable to acquire arms from traditional suppliers, special consideration should be accorded those LDCs which have already entered the arms export markets. Israel leads this group both in terms of total annual sales and the variety of its export lines. In 1976 Israel exported

* Aviation Week and Space Technology, October 15, 1979, pp. 18-19.

\$300 million in defense products and this rose to \$303 million in 1977. The Israel Export Institute has claimed that Israel projects sales of approximately \$675 million for 1979 of which \$450 million will derive from systems and components produced by Israel Aircraft Industries (IAI).^{*} India has continued to expand its share of the market in recent years. Its 1977 exports totaled \$38 million as against \$20 million for 1976. Its products are ideally suited to LDCs but that India is capable of meeting high standards can be seen in the joint venture being undertaken with the Swiss firm CONTRAVES in which India produces the fire control radars for the L-70 AA gun. The latter system is then exported by CONTRAVES. Brazil's arms export activities have grown through sales of its wheeled armored vehicles such as the CASCAVEL to other LDCs, particularly oil producing countries, and also military versions of aircraft manufactured by Embraer such as the EMB-111, a maritime patrol aircraft. South Korea and South Africa have both seen large increases in their export activities. In 1976 South Korea sold only \$5 million in military products but this rose to \$104 million in 1977. South Africa increased its sales from \$5 million in 1976 to \$47 million in 1977. Even Egypt, a net importer of weapons systems for many years, sold arms in the amount of \$47 million in 1977.

(This sudden rise may be accounted for by transfers of arms to Morocco.) Taiwan continues to export arms although its sales dropped from \$10 million in 1976 to \$5 million in 1977. There is yet another LDC in Southeast Asia, Singapore, which is making a serious effort to develop an armaments industry and expand its arms exports. The motivation in this case seems primarily commercial even though this industry does support the Singapore Armed Forces. Given Singapore's past as a major base for the British Royal Navy and Royal Air Force in the area, and the development of both physical facilities and a reservoir of skilled manpower, there is little doubt about the intent of this island state to become a major center for arms in the region. A large number of British armaments firms and a few American have established themselves there and formed the basis for the creation of local companies which produce a wide range of military products. They range from fast patrol boats to military electronics. For example, Avimo Singapore Ltd. produces a laser rangefinder for tanks. In

* Aviation Week and Space Technology, October 8, 1979, p. 57.

addition Singapore can perform major overhaul and retrofit of both aircraft and patrol boats.* While Singapore export sales are reportedly down to \$9 million in 1977 from \$20 million in 1976, it seems likely that its role as a supplier of both military products and services to LDCs will grow in Southeast Asia.

Accurate data for LDC arms production and exports is often difficult to obtain.** Furthermore, it may reflect local and topical situations (Egypt's arms export to Morocco is perhaps an example of this) but in general the trend is toward an increase in the number of LDCs which produce military products in sufficient amounts to permit them to engage in export activities. For this reason, and because LDCs which can export arms would themselves be unhappy over denial of access to the most advanced systems, it is likely that they would try to continue existing export patterns to other LDCs. When this LDC capability is added to the enormous number of LDC options inherent in the export practices of the industrialized world, East and West, there is every temptation to say that in almost every conceivable circumstance, a potential buyer will always be able to find a seller.

* International Defense Review, 9 August 1976, p. 657.

** World Military Expenditures and Arms Transfers, U.S. Arms Control and Disarmament Agency, October, 1979, "Statistical Notes and Sources," p. 23.

LIKELY LDC RESPONSES TO INTERRUPTIONS
IN DELIVERIES OF MILITARY SYSTEMS

The first LDC response to a situation in which deliveries from existing suppliers of military systems and products were interrupted or halted would be to seek alternate suppliers. From the discussion above on the number and variety of arms producers and exports in the world today, many of them LDCs themselves, it is evident that this course would probably meet with some degree of success although at some cost to the importing country. It might be made difficult for LDCs to import systems with high visibility such as aircraft and tanks but if the LDCs were interested in upgrading existing systems in order to achieve an advantage in a regional confrontation, acquisition of the modular components necessary to such retrofit should not prove difficult. In this connection, it is important to bear in mind that there exists in the market economies of the West an intricate network of arms dealers who function as middlemen between producing firms, defense ministries and the eventual customer. They deal in military stocks and surpluses of all kinds and would be helpful in obtaining some upgrade items. Finally, there is the possibility of resorting to illegal methods to obtain military products. It has been suggested that South Africa, in its program to develop extended-range medium artillery ammunition, utilized clandestine channels to acquire both 155 mm shells and the expertise to duplicate them from the American firm which developed the process.*

In the event that LDCs could not purchase military systems or the components required to upgrade such systems, some LDCs would almost certainly try to produce the items indigenously. Even for very advanced LDCs this would pose certain difficulties even though they might possess the necessary industrial infrastructure. It is recognized that in the manufacture of weapons systems under license, and also those which have been locally designed, many components are of foreign origin. This is not necessarily a reflection of the LDC's inability to master the production techniques but rather because the component can be acquired more cheaply on the open market. For example, about 75 percent

* The Washington Post, Outlook Section, August 5, 1979,
"Smuggling Arms to South Africa," David C. Martin and John Walcott, pp. B 1 and 2.

of the value of the components of the new Israeli main battle tank, MERKAVA, are manufactured in Israel.* 12 percent are imported from abroad and this includes the engine. The remainder of the components are assembled in Israel from parts manufactured abroad. It is claimed by Israeli officials that the tank as a whole can be manufactured more cheaply in Israel. On the other hand, if certain of the imported components had to be made there as well it would drive the cost up because of the investment Israel would have to make in developing appropriate manufacturing capabilities. The Israelis might be able to produce a suitable engine and transmission but at a great expenditure of time and money. This practice, i.e., a 'make or buy' decision, is followed throughout the West and certainly in all market economies. Nevertheless, it is believed that some LDCs could produce some systems and upgrade others to achieve local military advantage if they were prepared to make the investment. A caveat is in order, however, because virtually none of the LDCs who might possess the skills to produce the weapon, could continue to do so if there were also a cutoff of the prerequisite raw materials and semi-finished goods on which such production depends. The industrial world of the LDCs is made in the Western image, by and large, rather than the autarky espoused by the East and as a result some LDCs rely on imports of a wide variety of items which are either not available in their countries or could be developed only at considerable expense. As a given, therefore, it could be said that Israel, India, Brazil, South Africa, Argentina, Yugoslavia, the two Koreas, Taiwan and Singapore all have the capability in greatly varying degrees to produce some of the military products required either by themselves or other LDCs. A judgment as to which products they could manufacture to achieve what precise degree of upgrade or modification would depend on the product and the performance levels desired. At present, it is clear that Israel and India have the technology infrastructure including skilled manpower necessary to produce military systems and products without foreign assistance although Israel's ability to do so would depend very much on continued deliveries of raw materials. Brazil, while lacking the refinements in industrial infrastructure possessed by the Israelis, does have the raw materials and could in

* International Defense Review, March 1979, p. 317.

time produce many weapons systems and modular upgrade components if the decision were made by the Brazilian Government to make the necessary investment. This formulation must be tentative, however, because (1) there are many aspects of the relationships between these countries and Western states in matters of industrial collaboration which are unclear, and (2) it represents a 'snapshot' of the situation as we perceive it today; in ten years, others among the LDCs will probably have attained similar levels.

It is evident from the foregoing that indigenous production of military products as an alternative is an option reserved to a relatively small number of LDCs. Even they may find it difficult to follow this path because the cessation of normal supplier-recipient relations could affect many production processes and force LDCs attempting indigenous production to make significant investments in ancillary production facilities which they would not do if they were able to obtain the products freely. It is the purpose of this paper then, to examine the hypothesis that there are products not normally controlled to LDCs which embody dual-use technologies and which could be exploited by LDCs to upgrade weapons systems. In this case we will examine a range of systems which we believe could be destabilizing if used in certain regional conflicts and determine which, if any, civil products could be imported by an LDC and adapted to the systems in question as part of the upgrading or modification process. This is not to assess critical dual-technology production processes which are used in manufacturing weapons systems and components. This is the province of another study in this series.* In this paper we will treat exclusively those commercial products which embody dual-use technologies but are in fact sold in the open market by the U.S. and other countries for use in civil systems.

* See Volume IV, Essays on the Role of Coproduction and Dual-Use Technology in the Development of LDC Arms Industries, September 1980, (Unclassified).

POTENTIALLY DESTABILIZING MILITARY FACTORS
IN REGIONAL CONFRONTATIONS

There are numerous scenarios for regional confrontation between LDCs which might cause supplier states to interrupt arms deliveries thus prompting LDC actions in anticipation of, or in response to such interruptions. These actions could include exploitation of dual-use technology products as a means of improving the effectiveness of individual weapons systems. One might eliminate from consideration, however, those confrontations in which one or more of the LDCs involved was seen to be a superpower proxy and the confrontation one in which vital superpower interests were at stake. This has been the case to date in the Arab-Israeli conflict and as a result arms deliveries not only continued but were expanded to meet participants' needs as the conflict deepened. Understandably, it is not always possible to separate confrontations of this type from others of a purely regional nature because big power interests in today's highly interdependent world increasingly tend to involve these powers in local conflicts. Assuming no such involvement, however, there are other differences between potential adversaries and their military potential which will bear on the role of dual-use technology products. Conflicts between some LDCs would be conducted at relatively high levels of military technology on one or both sides. This would be true of India and Pakistan in South Asia and of Argentina and Brazil in Latin America. In addition to possible conflicts between nations at this stage of the development, there are those which could arise between LDCs at lesser stages of industrial growth but still possessing impressive military capabilities. Boundary disputes, disagreements over oil exploration rights, all exacerbated by traditional rivalries, could produce such conflicts. These same causes can impel even the least developed countries toward military solutions but in this case, the level of military technology and the numbers and skills of the forces involved on at least one side would be relatively low. In this category would come states such as El Salvador and Honduras or Ecuador and Peru in Latin America, Uganda and Kenya in Africa, or the Philippines and Vietnam, (e.g., over the Spratley Islands) in Southeast Asia. These same military factors also affect civil conflicts within states in which externally based or supported opposition elements ('liberation movements') may or may not play a role. Noteworthy

here would be the Rhodesia-Zimbabwe situation and Morocco's war with the Polisario movement in the Western Sahara. A word of caution, however, with regard to the levels of military technology involved. The veritable explosion in arms traffic in recent years has meant that even the lesser developed countries of the Third World have acquired increasingly effective weapons even though in some cases they would be considered obsolescent by developed countries or the more advanced LDCs. For example, in 1968 and 1969 Ecuador had no arms imports, in 1975 it imported \$53 million and by 1977 had reached a total in annual imports of \$142 million. Peru, on the other hand, primarily because of its Soviet connections, went from \$48 million in 1969 to the staggering level of \$408 million in 1977. To cope with the Polisario movement alone, Morocco's imports shot up from \$7 million annually in 1971 and 1973 to \$220 million and \$190 million in 1976 and 1977 respectively.* The level of military technology needed by Morocco in this struggle can be seen in the recent decision by the President to recommend to the Congress the export of such modern weapons systems as the Bell COBRA helicopter gunship and the Rockwell OV-10 counter-insurgency aircraft. Also eliminated from consideration were those weapons systems or military products which are so purely military in their design and application that no civil products exist which could be imported through commercial channels as a substitute for such systems or serve as a technique of upgrading. In this category are infantry weapons, artillery, aircraft ordnance, naval ordnance and ammunition. In a somewhat similar category are those weapons which are manufactured in such quantity by so many countries including some of the most underdeveloped countries, that it would be unreasonable in the extreme to assume that their sales could be or would be curtailed by producing LDC nations. Here again we would include infantry arms and artillery even though it is recognized that in very primitive regions a preponderance of such items on one side or the other could affect the balance. Such situations are rare today as we have indicated and it is likely that they will become more so in the future as additional arms transfers take place.

Within the framework of the kinds of possible regional confrontations described above there are military

* World Military Expenditures and Arms Transfers, U.S. Arms Control and Disarmament Agency, October 1979, is the source of arms export data in this section.

situations in which weapons systems upgrading or retrofit arising from the possible application of dual-use technology products could affect the battlefield balance. Set forth below are those factors in air, land and sea engagements which could produce a destabilizing effect:

Air Engagements

- all weather capability
- improved communications
- increased range/improved navigation
- increase in speed/maneuverability
- increased weapons range and accuracy

Land Engagements

- improved communications, command and control
- night/day operations capability
- improvements in range and speed of armored vehicles
- improvements in battlefield reconnaissance
- anti-armor capabilities
- detection of and defense against air attack
- increased weapons range and accuracy

Sea Engagements

- improved ASW capabilities
- improved propulsion systems for increased speed, range
- improved communications, navigation, night vision
- increased weapons range and accuracy

EXPLOITATION OF DUAL-USE TECHNOLOGY PRODUCTS TO
UPGRADE POTENTIALLY DESTABILIZING SYSTEMS

Consideration of the various circumstances in which LDC adversaries in regional confrontations might exploit civil products to achieve upgrade of potentially destabilizing weapons suggests that resulting impacts of such upgrading on the battlefield balance would be essentially proportionable to the degree of sophistication embodied in the weapons in use on both sides in a regional conflict. It seems generally true that the more primitive the level of military skill and technology involved, the more likely it is that the introduction of a weapons system of only modest capabilities (by advanced, state-of-the-art standards) could upset the balance if possessed by only one side which thereby achieved tactical advantage from its introduction. At the other end of the spectrum, the higher the level of technology exhibited by the opposing sides in a conflict, the more difficult it will be for either opponent to exploit dual-use technology products to achieve a destabilizing impact. In such cases, it is likely that the tanks involved will already have undergone some retrofit and that the aircraft will have been modified to give them some modern avionics capability. On the other hand, as we shall note in the discussion of the application of civil products to specific systems, it is the advanced LDC which would be technologically the most qualified to adapt civil products to military needs. Thus, if a conflict arose, and the opposing sides were unable to acquire new weapons systems or modular upgrade components from normal suppliers with which to achieve a battlefield advantage, and could not, for whatever reason, produce them indigenously, they would seek those applications of civil products to weapons systems which could have maximum impact. The products selected and the weapons systems to which they might be adapted will vary, not only as a reflection of the capabilities of the weapons in the inventories of both sides, but also of the technology required to make the needed modifications.

With this in mind, we have chosen:

- Surface-to-Surface Missiles (SSMs)
- Attack/Ground Support Aircraft--fixed and rotary wing
- Tanks
- Fast Attack Craft - Missile

For each of the systems selected we will consider:

- the rationale for its selection;
- the state of the art where appropriate;
- the upgrading or improvements normally applied to such systems; and,
- the degree to which dual-use technology products could be adapted to achieve comparable improvements.

SURFACE-TO-SURFACE MISSILES (SSMs)

It may seem that surface-to-surface missiles have little relevance to LDCs and even less to the possible utilization by LDCs of dual-use technology products in developing or modifying them. This would be the case if consideration of this family of weapons were limited to strategic, long-range, ballistic missiles of the intercontinental variety. There are several variations, however, of the SSM which have already interested some LDCs and are likely to attract the attention of others over time. These include both guided ballistic missiles and cruise missiles with ranges which may extend from tactical distances to several hundred miles or more.

Ballistic Guided Missiles

The advantages which would accrue to an LDC in having a ballistic guided missile capability do not differ from those enjoyed by the major powers who have already developed and deployed them in strategic modes as well as for battlefield support. SSMs permit strikes against an adversary's rear areas, supply dumps, railheads, airfields, troop concentrations, etc. which maximize losses to the defending side while minimizing the losses which would be suffered if such attacks were made with manned aircraft against well-defended targets. The big powers have concentrated on the nuclear delivery capabilities of SSMs but LDCs could use high explosive or chemical warheads. To date there is little evidence that LDCs have actually developed and deployed a ballistic missile. Egypt began a program in the early '60s in collaboration with German specialists and although President Sadat threatened use of an "Egyptian long-range missile" in the 1973 war, it is not believed that the German-inspired program ever developed guidance systems with sufficient accuracy for effective employment.* Israel, in collaboration with the French firm Marcel Dassault, is reported to have developed a 450 km range missile which may have been tested in 1968. The Israelis have denied the existence of a missile program and no evidence is currently available to support or reject these denials. It seems reasonable, however, to assume that

* Jane's Weapons Systems 1977, p. 49.

the Israelis have made progress in this area if one takes into consideration the extent of the original French assistance and the level of Israeli technological advances in other areas.* India has had a space launch vehicle program underway for several years which could have provided a technology base applicable to the development of ballistic missiles. Its first indigenously designed and produced launch vehicle, the SLV-3, was launched on August 10, 1979 and was apparently a total failure.** It is not clearly evident, however, from readily available information how far the Indians have progressed in also developing ballistic missiles. Few LDCs have the industrial infrastructure of an India or Israel which would be necessary to the development of a ballistic missile system. South Korea has apparently taken another tack in efforts to develop a surface-to-surface missile capability.+ This apparently has involved the exploitation of dual-use technologies and products to modify the NIKE-HERCULES in its surface-to-surface mode. A later volume in this series investigates this process.++ In consequence thereof, this paper will not treat LDC development of ballistic missiles in the same depth as the other systems examined. It is clear, however, that whether an LDC is engaged in the development of a new system, or in the modification of an existing SAM system to a surface-to-surface mode, there are many applications of dual-use technologies or their embodiments in products which are applicable to the testing and production of the ultimate version. This point is made in an unclassified appendix to Volume III which lists those dual-use technologies and products of potential interest.

Cruise Missiles

Perhaps because of the prominence they have been accorded in the context of debates related to SALT II, there is an impression that cruise missiles represent a

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- * Jane's Weapons Systems 1977, pp. 49-50.
 - ** Air and Cosmos, 25 August 1979, p. 42.
 - + Aviation Week and Space Technology, October 22, 1979, pp. 62 and 63.
 - ++ Volume III, A Study of the Exploitation of Dual-Use Technologies: South Korea, September 1980, (Confidential).

new system embodying high technologies in propulsion and guidance which will be applied primarily to strategic nuclear delivery requirements. This is only partially true and relates to developments in the United States of small, turbo-fan engines with low fuel consumption and greatly improved guidance systems which utilize terrain contour matching and inertial navigation. Cruise missiles are in fact not new; they were introduced in NATO in the 1950s and in various modes are currently deployed by the USSR in coastal defense and battlefield support roles. In essence, a cruise missile is an unmanned aerodynamic vehicle with a stand-off capability which can be guided to its target and inflict damage thereon. By this definition, cruise missiles can either be highly sophisticated as in the case of the TOMAHAWK, or extremely primitive applications in which an obsolete aircraft is packed with high explosives and remotely piloted to its target destination. The target can be exclusively military in character such as supply dumps or the cruise missile could be employed indiscriminately against populated centers primarily for the psychological effect. For this reason, we believe they may become quite attractive to LDCs who can use them in battlefield support and other roles where for a minimum investment they can obtain maximum impact. Cruise missiles lend themselves to the application of dual-use technology products which could be exploited by LDCs with relatively modest manufacturing capabilities. This will be demonstrated by examining the major components of a cruise missile system and relating them to those dual-use technology products which could be applied to them.

Airframes. As indicated above, the least complex approach to devising a cruise missile would be to utilize obsolete aircraft with the existing or improved propulsion system (see below). Thus, the F-86 jet fighter was modified by Flight Systems, Inc. of California to serve as a target drone. Specially manufactured drones as well as remotely piloted vehicles (RPVs) could be converted to cruise missiles. They are available from at least thirty firms in over twelve countries, primarily in military versions. On the other hand, there are RPVs with specific, civilian applications which could be imported by LDCs to meet cruise missile requirements. These applications include forest surveillance, aerial photography, pipeline surveillance, flood control, air sampling, etc. RPVs designed for these

applications are manufactured by South Africa and Saudi Arabia. It is not unlikely that some of the RPVs developed for battlefield surveillance could be considered for civil surveillance applications of the type noted above and exported by some countries. Aside from import of air frames or utilization of obsolete light aircraft, it is probable that indigenous construction of air frames suitable for some cruise missile applications would present minimal problems for many of the LDCs we have studied. This would certainly be true for those already engaged in aircraft production but might also apply to some LDCs with extensive experience in depot-level maintenance, rebuilding and repair of aircraft.

Propulsion Systems. Ideally, the cruise missile would be equipped with low cost, expendable jet engines with good fuel economy for all but short range application. The state of the art is best expressed in the Williams Research F 107, a two-shaft turbofan producing 600 lbs. of thrust. This engine was expressly developed for use with the new U.S. strategic cruise missiles, ALCM and TOMAHAWK, whose long ranges demand fuel economy. For shorter ranges and for the kinds of applications which many LDCs would have for cruise missiles, the difference in fuel consumption between turbofans and turbojets is not all that great. For example, the difference in fuel consumption between a turbofan and turbojet both developing 400 lbs. thrust would be roughly 120 lbs. per hour. For a 500-mile range missile, the added weight of fuel would be 150 lbs. at the most. Thus, turbojets remain candidates for cruise missile application. In the U.S. Teledyne CAE produced its J 402, a turbojet with 640 lbs. of thrust for ALCM applications but lost out to Williams Research, while in the United Kingdom, the firm NPT also makes small turbojets for use in drones or RPVs such as the FR 500 which can be modified to carry out a variety of roles.

There are, however, larger turbojets which would be suitable for cruise missile application. The Teledyne CAE 352/356 is a good example both in terms of its specifications and likely availability. The CAE 352-5A obtains 1,025 lbs. of thrust and in military versions has been used to power RPVs and target drones such as the Teledyne Ryan model 255 Electronic Warfare RPV. The CAE 352-5A was also used to power a Cessna trainer and has been certified by

the FAA (CJ-69-1025). Originally, the CAE 352-5A was the French Turbomeca MARBORE which Teledyne CAE produced under license. The French firm continues to produce a variety of small turbojet engines which could be adaptable to cruise missile requirements. Such engines also have a variety of civil applications. In any event, the U.S. Commodity Control List (CCL) exempts jet engines of less than 5,000 lbs. of thrust from the requirement to obtain a validated license for export control under CCL Item 1460A. This position is modified somewhat by paragraph (a) (2) of CCL Item 1460B which requires validated licenses for the export of certified engines "which have been in civil use for 3 years or less." This should pose no problem for an engine such as the CJ 69 (MARBORE). It develops less than 5,000 lbs. thrust and has been in use for several years. This suggests that unless other modifications are made in export regulations with regard to jet engines of the type which could be adapted to some cruise missile requirements, such engines could be easily purchased in the United States and in other countries as well. Installation of such engines in a cruise missile airframe could be accomplished by virtually any one of the LDCs selected for special study. It would, however, severely test any LDC which was incapable of performing maintenance on aircraft in its possession.

Guidance. Understandably, the kinds of guidance systems which LDCs employ in cruise missiles will depend on the missions for which the cruise missiles were developed but also on the level of competence possessed by a given LDC in the communications and electronics fields. For limited range applications, ground control via radio command is the simplest approach. The range can be extended by using a programmed flight plan and an autopilot which could be responsive to some flight path changes directed via a data link. These all involve operations to-the-horizon only (although if mid-course guidance were available from an aircraft, this could be extended). For longer ranges, particularly with RPVs, use has been made of LORAN (which would not work, of course, in areas without LORAN beacon systems in operation). In any of the guidance approaches described, the system would have to be augmented by some active homing device if any degree of accuracy were desired. This would not be needed if the mission involved saturation attacks on cities for psychological purposes or if the warheads contained chemical agents. Perhaps the best

combination of guidance systems would be the use of an inertial guidance package plus an active or passive homing head. The availability of inertial guidance systems (INS) used in civil applications is the subject of Volume II in this series.* As for terminal guidance, this would pose problems for most LDCs, regardless of the system used, if the homing head is expected to function independently. For example, as the active radar head locks on to radiation from the target it in fact assumes control of the missile's flight-path. Systems for transmitting data from the homing head to the control surfaces of the missile vary but can be complex indeed, utilizing advanced technology such as on-board microprocessors. As will be discussed in sections on Attack Aircraft and Tanks, there are civil products which might be obtained to form some elements of such a system, but extensive modification would be necessary and this would be possible only in the case of those LDCs who have already demonstrated a capability for producing similar guidance systems for such applications as anti-ship missiles. At present this would be limited to Israel and perhaps India. Thus, it seems likely that for most LDCs, use of cruise missiles as a factor in regional conflict will be limited to relatively limited ranges. It is not the airframes or propulsion systems which will pose problems of acquisition or application, but rather guidance.

Warheads. There are no civil products which could be usefully considered in developing warheads for cruise missile application. If an LDC wished to experiment with chemical warfare (CW) agents, it would probably not be difficult to purchase the necessary toxic materials. Much more critical, however, would be the techniques to be devised for incorporating the resultant chemical warfare agent in a warhead, insuring that it could be handled safely and that it would have the desired effect when employed against an adversary.**

* See Volume II, Exploitation of Civil Inertial Navigation Systems for Military Purposes by Less Developed Countries (LDC's), September 1980, (Confidential).

** See Volume III of this series for a more complete treatment of the technical/operational issues in possible chemical warhead developments.

ATTACK/GROUND SUPPORT AIRCRAFT -- FIXED AND ROTARY WINGRationale

Attack/ground support aircraft were selected for study because they are in general use in most LDCs and have the potential in varying degrees for destabilizing the battlefield balance. Such aircraft, regardless of their vintage, all have the capability of delivering destructive force against surface targets. Such attacks may be carried out in frontal areas in cooperation with friendly ground units or independently against targets deeper in the rear. The extent of destabilization will naturally depend on several factors: age and technical characteristics of the aircraft involved, nature of opposing air defense system, pilot skill and experience, etc. Many of these factors may be affected by improving or upgrading the attack aircraft in question. Such upgrading is underway constantly in the air forces of both the LDCs and developed powers and is normally accomplished through purchase of military modules or by arranging for an entire retrofit program. Were it no longer possible to accomplish this, LDCs might find that some of the upgrading considered essential could be carried out through the application of civil products. To determine this, we shall briefly trace the development of attack aircraft, from converted trainers to the most advanced state of the art, noting the kinds of systems upgrading which have already taken place, and finally examine those dual-use technology products which might be adapted by some LDCs through retrofit if the military products were no longer available.

Development of Attack/Ground Support Aircraft (Fixed Wing)

In several LDCs, light aircraft have been modified for ground support or counter-insurgency roles. For example, by restressing the airframe, adding underwing hardpoints and pods, Argentina made use of the CHINCUL trainer, an aircraft derived from the Piper CHEROKEE ARROW, for training pilots in ground attack roles. India developed the KIRAN Mk I as a jet trainer in the early '60s. In the late '70s it was upgraded and modified to serve as a light attack aircraft

in counter-insurgency roles. The original Rolls-Royce VIPER 11 turbojet was replaced by the ORPHEUS for increased thrust, bomb and rocket pods added along with new gunsights. Both jet engines are manufactured in India under license. The predilection of modern air forces, when faced with ground support requirements, to convert training aircraft to this role, is no better illustrated than in the development of the U.S. Air Force's A 37 from the T 37 trainer. The latter was developed as a jet trainer in the late '50s; one version of the T 37 was produced with wing tip fuel tanks and racks for bombs or air-to-air missiles and delivered to several LDCs with insurgency problems. By the mid-60s, American requirements for ground support in Vietnam, resulted in extensive modifications to the original trainer. The new version, the A 37, was equipped with General Electric J 85-GE-5 turbojets to replace the less powerful Teledyne J 69s, and given more complex avionics and a wide range of ordnance. Another example of the trainer to attack aircraft upgrade can be found in the Japanese decision to develop the Mitsubishi F-1 close support aircraft from the T-2, a supersonic advanced trainer. In this case, the original jet engines were retained (two Rolls-Royce/Turbomeca ADOUR turbofans produced by Ishikawajima-Harima of Japan under license) but the second cockpit was converted to an electronics bay and racks added to the wings which permit employment of bombs, air-to-ground missiles, anti-ship missiles, etc. The electronics systems in this aircraft reflect the modular approach to upgrading and the utilization of components from a variety of industrialized countries: British Ferranti inertial navigation system; Mitsubishi Electric "head-up display" manufactured under license from Thomson-CSF of France, and a Japanese-designed fire control system and bombing computer.

Current Attack/Ground Support Aircraft

It is likely that many countries will continue to upgrade light aircraft including trainers for specialized ground support or counter-insurgency roles. As the Japanese conversion from trainer to close-support aircraft suggests, the results of such upgrading can be impressive. As attack and ground support requirements became increasingly complex, however, a tendency developed to design aircraft primarily for those roles. A good example of the state of the art is

the Fairchild A 10 ground support aircraft. Developed in the '70s and delivered to USAF tactical wings in 1977-78 in a single-seat version, it will be supplemented by a two-place night-adverse weather aircraft now undergoing evaluation. The operation of its complex weapons and electronics systems will require both a pilot and a weapons systems officer. Its electronics suite will include a multimode radar with these functions: ground moving target indicator, ground mapping, terrain following/avoidance and threat detection, plus a forward looking infrared (FLIR) system to which a laser rangefinder is boresighted. Armaments range from the GE seven barrel 30 mm cannon in the nose to an awesome array of precision guided bombs and missiles. This aircraft, in its design, systems and weapons, represents a level of technology, particularly in systems integration, which no LDC today could achieve. Nonetheless, its individual components are modular in concept and are all available (albeit at lesser levels of sophistication) from non-American sources. For example, the export version of the Franco-British (SEPECAT) tactical support aircraft JAGUAR includes in its electronics suite a Thomson-CSF AGAVE multi-purpose radar which can perform many of the functions of the A-10's Westinghouse multimode radar described above. It is the JAGUAR which has recently been purchased by India and may also be built in India under license.

As the costs of aircraft design, development and production mount, resistance has developed to the design and development of single mission aircraft such as the A 10. Increasingly, and particularly in the European aircraft industry, countries have been attracted to the "multi-role" concept in which a single aircraft with some modifications for each role, is able to carry out close support and air strike missions, and also serve as an air superiority fighter. Even the JAGUAR, noted above, is used by the British and French air forces as an advanced trainer as well as a tactical support aircraft. Another example, the TORNADO, produced by the British-German-Italian firm Panavia, is a multi-role aircraft capable of both close support and air superiority. In this aircraft, the modular concept is vital. First, because the multi-role character of the aircraft requires component interchangeability, and second, the international character of the producers often means that individual nations in the consortium will prefer to use their own products. For example, the multimode

radar on the Mk 1 attack version is a Texas Instrument RADPAC built under license by Panavia. The Mk 2, the air superiority version for the RAD, uses an interception radar developed by British Marconi Aviation.

Development of Ground Support Aircraft (Rotary Wing)

The recent appeal of King Hassan of Morocco for AH 1 COBRA helicopter gunships for use in his struggle with the POLISARIO movement in the Western Sahara underlines the important tactical support role of the rotary wing aircraft. There are, of course, many military roles (transport, medical evacuation, ASW, etc.) which helicopters play but this paper will concentrate on their close support of ground forces. An excellent example of dual-use technology, some of the best known attack helicopters were also produced in civil versions. This was true of the Bell UH-1 IROQUOIS "Huey" which was developed in the late '50s and used throughout the Vietnam War. Successive versions of the UH-1 were developed in which new engines increased power and the armaments suites were improved. The AH-1 COBRA, noted above, was developed in the mid-60s as a specialized gunship with a smaller, narrower fuselage. The introduction of specially designed armament turrets, external pylons for rockets, TOW anti-tank missiles, etc. improved communications and weapons management systems for target acquisition and fire control. Newer versions will be given 30-mm Hughes chain guns and new electronics to include Doppler navigation systems, head up displays, sophisticated electronic warfare systems and a Marconi-Elliott fire control computer. The latest in state of the art for helicopter gunships will be the Hughes AH 64, prototypes of which are now undergoing evaluation. It will be much more powerful (possessing two General Electric T 700-GE 700 turboshaft engines each with 1536 shaft horsepower compared with the one Pratt and Whitney Canada T400-CP-400 turboshaft with 1800 shaft horsepower used in the COBRA) and will have the most sophisticated all weather navigation and fire control systems yet seen on an attack helicopter. Its principal weapon will be the new anti-tank missile HELLFIRE, plus the TOW AT missile and a full complement of other rockets as well as the Hughes 30 mm gun. Of the foregoing, the UH-1 (and its follow-on models), is the most widely available abroad. It or variations of it are produced under license in Taiwan, Japan and

Italy, with the latter country active in export. Italy has also designed its own Agusta 109 in military and civil versions. Agusta 129, now in development as an anti-tank helicopter, is also of indigenous design. The military version of another U.S. helicopter, the Hughes 500 D, is produced in South Korea under license whence it has been exported to LDCs such as Israel, Colombia and Mauritania. There are, of course, numerous, other helicopters of European design in production. France's Aerospatiale produces many types some of which can be fitted for a ground support role. For example, the PUMA and Super PUMA can be fitted with 20 mm cannon, missiles and rockets. Smaller craft, such as the DAUPHIN SA 360, also comes in a military version (the 361 H, which is fitted with a HOT anti-tank missile). Even lighter French helicopters such as the Alouette can be modified to carry out an assault role. In addition, the firm MBB in West Germany makes the BO 105 which can be equipped with HOT anti-tank missiles. Another version of this craft with both civil and military applications will be jointly manufactured in Japan by MBB and Kawasaki. At the same time, the French and Germans have under development an anti-tank helicopter designed specifically for this role in the 1980s. The French have also joined with the British in joint production of a family of helicopters of which one is the Westland LYNX. Of all of the current European designs, the LYNX most closely resembles the American gunships; its 20 mm cannon is mounted in an Emerson Minitat (tactical armaments turret) beneath the cabin, it carries anti-missiles such as HOT and TOW plus modern navigational and weapons control equipment. It appears reasonable to assume that over time, European manufacturers will make progress in developing helicopters for anti-tank purposes which will respond to NATO needs. In the meantime, the civil/military versions they now produce would seem to be more than adequate to the needs of LDCs and would require minimum upgrading and modification. Many of them, particularly the French helicopters, are now manufactured in LDCs (Brazil, India, Indonesia and Yugoslavia).

Exploitation of Dual-Use Technology Products in Upgrading Attack/Ground Support Aircraft. Fixed wing aircraft can be upgraded and their effectiveness improved by changes in the propulsion system and by improvements in the electronics systems. These same factors apply to rotary wing aircraft, of course, and these will be mentioned in this section where

applicable. The overall issue of civil helicopters, certainly a dual-use technology product, and their conversion to military applications has already been examined.

Propulsion Systems. It was evident in the account of trainer aircraft conversion to attack roles, that a key factor in such upgrading is the power plant. For this, modern turbojet or turbofan engines are required yet their manufacture presents serious difficulties for all but a very few LDCs. Problems in design, materials, controls and manufacturing techniques are such that even those LDCs which produce older models of U.S. or European jet engines under license would find it difficult to design and produce their own engines without any assistance from abroad. This is why such engines, when required for military aircraft applications, are often purchased abroad and in these cases would be built to military specifications. Because of the supersonic speeds, rapid climb and high maneuverability required by some military aircraft, particularly air superiority fighters, the jet engines used will be augmented by afterburners to achieve peak thrust. Despite the foregoing, and recognizing that the retrofit requirements of many LDCs will be relatively modest when it comes to improvements in attack/ground support aircraft, it may indeed be possible to utilize commercially available jet engines if comparable military versions are not obtainable. For example, Garrett Corporation together with Volvo Flygmotor of Sweden is developing a military turbofan engine in the 4,500 lbs. thrust. This is a militarized version of the 3,500 lbs. thrust TFE 731 which is used extensively in business but also by the Spanish Air Force in its CASA 101 trainer. The latter aircraft is also designed for use as a high performance light attack/close support aircraft with a weapons suite and electronics backup which make it an effective system. If greater power is needed to upgrade a heavier aircraft, or permit great weapons payload, there are jet engines of greater thrust used in commercial airline or business jet applications which might be available. For example, the CJ 805-3 turbojet and the CJ 805-23 turbofan, which are used to power the CONVAIR 880 and the CORONADO 990, respectively, are civilian derivatives of the GE J 79, a military jet of about 10,000 lbs. thrust. Another possibility would be the civilian versions of the General Electric TF 34 which is used to power the new USAF attack/ground support aircraft, the Fairchild A 10. The TF 34 develops circa

9,000 lbs. of thrust. The civilian version CF 34, for commercial and business aircraft, will develop 7-8,000 lbs. of thrust. It would appear then, insofar as exports from the United States and its Allies are concerned, that if a jet engine has less than 5,000 lbs. thrust, and has been in civil use for three years or more, it can be exported without a validated license (CCL Items 1460A and 446)B). This would fit the Garrett engine as well as the Rolls-Royce VIPER (both civil and military applications). Presumably, if an aircraft required more than 5,000 lbs. thrust and a larger engine were sought, its export would be possible under validated license. Jet engines (turbo-shafts) for helicopters should not pose a problem insofar as moderate power upgrading is sought for a civil helicopter which will be converted to close support or anti-tank roles. For example, the LYNX (see above), best of the European anti-tank helicopters, is powered by two Rolls-Royce GEM turboshaft engines each of which developed approximately 750 horsepower. CCL Item 1460A requires a validated license only for turboshaft engines of more than 2,500 horsepower. It should be borne in mind, however, that if an attempt were made to increase the power of a helicopter propulsion system, it would also be necessary to incorporate new rotor drives. These helicopter power transmission systems are usually designed and produced by manufacturers who specialize in their development and production.

Electronic Systems. The electronics functions associated with a military aircraft are:

- Flight control
- Navigation
- Communications
- Weapons management
- Electronic warfare

These functions and the components which are associated with them will be considered individually. In many cases they are installed in or added to aircraft on a modular basis and it is possible that civil products could be substituted for some of them. It is important to recognize, however, that in modern aircraft these functions are mutually supporting and integrated under control of a central computer. This is the case for new aircraft and increasingly the same pattern is being followed in the production

of retrofit packages. Figure 1 below illustrates this concept for the Dassault MIRAGE 2000. This aircraft, of course, is a supersonic air superiority interceptor but the approach is similar to that which would be taken in integrating the electronics of modern attack/ground support aircraft. (See earlier discussion of the Fairchild A 10).

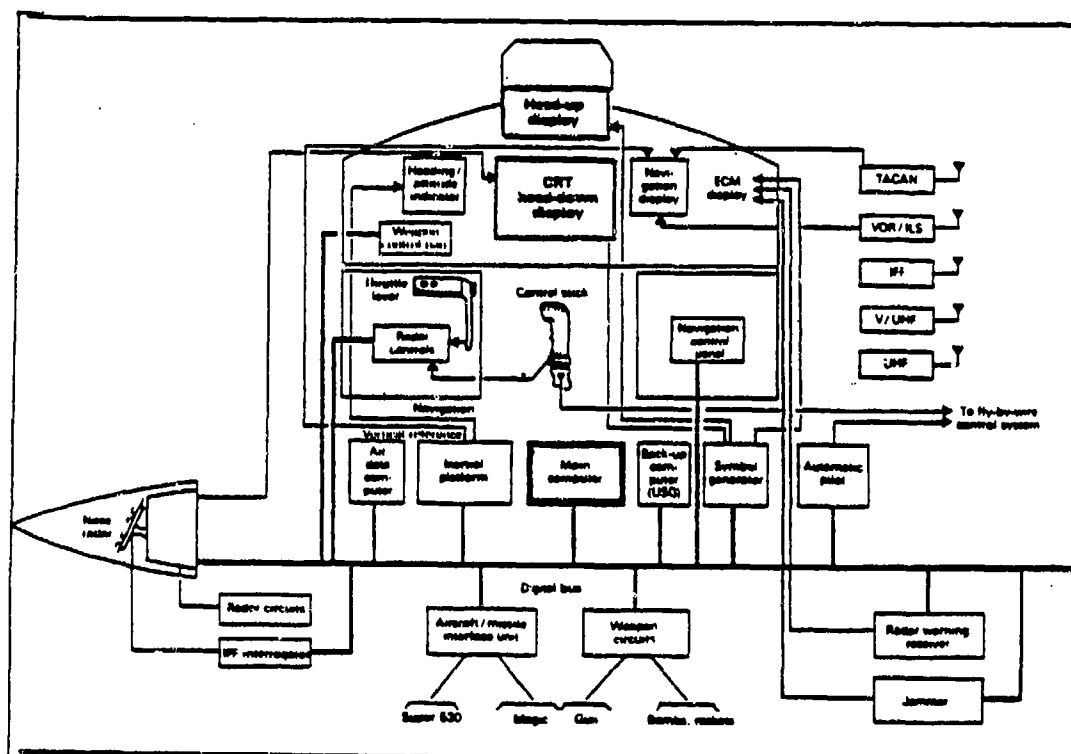


Figure 1. Integrated Avionics in a MIRAGE 2000.

Just as the centralized electronics systems depicted above reflect the current state of the art, it is also possible to conceive of an LDC seeking to convert a very basic aircraft to a ground attack role. If the aircraft had no communications and if its flight control and navigation

equipment consisted only of an air speed indicator, fuel gauge and magnetic compass, almost any addition would constitute a significant improvement. Such additions could easily utilize dual-use technology products and could be effected with minimum difficulty or experience. It is unlikely, however, that in today's world there are many LDCs at this rather primitive level of military aircraft development. In most cases, LDCs would seek incremental improvements in vintage attack aircraft which would provide all-weather operations, independent, long-range navigation, increased weapons accuracy and capabilities, particularly if an attempt is to be made to adapt civil products to these requirements.

- Flight Control. There exists today a wide variety of civil flight control systems such as instrument landing systems (ILS), automatic pilot/flight directors, radars providing an all weather capability, landing radars (Doppler), angle of attack sensors, etc. In some cases, military radars were developed from civilian airborne weather radars. This is the case with the British Ekco E 290 weather radar which in its military version not only performs long-range weather detection but is also suitable for terrain mapping and target detection. Radars and other flight control systems are all available in civil modes through commercial channels. Export from the U.S. would be permitted under a validated license (see Item 1501 A on the CCL) and all these systems are also manufactured in many industrialized countries. Thus, successful application to an attack aircraft would depend on the specific requirements of the aircraft, the level of upgrade desired and the qualifications of the technical personnel charged with the installation.
- Navigation. Here again, the civilian market offers the full range of modern navigational equipment. While the United States leads in the development of such systems for both military and civil aircraft, other countries have developed extensive lines in which some items are of local design and others are manufactured

under license. For example, Standard Elektrik Lorenz, a West German ITT subsidiary, has available a medium range navigational radio system (TACAN), a Doppler navigation system (LDNS), VHF Omnidirectional Radio Range, (VOR), and Direction Measuring Equipment (DME). If it were necessary to avoid external references in navigation systems as would be the case with TACAN and LORAN, the aircraft would require an inertial navigation system (INS). Also, an inertial platform would be necessary or at least desirable for optimum performance of certain weapons. Clearly, each of the navigational aids described above could enhance the performance of an attack aircraft but its application and integration with other elements of the electronics systems would pose technical problems.*

- Communications. An attack aircraft such as the Fairchild A 10 would have the following communications transceivers: UHF/AM, VHF/AM, VHF/FM. Finding the civil versions which match military specifications in numbers of channels, computerized, channel selection, speed of switching, power output, etc. would not be excessively difficult. There is a wide range of equipment covered under Item 1531 A (c) of the CCL which can be exported with a validated license.
- Weapons Management. The operational reason for an attack aircraft is the ability to deliver accurately aimed firepower from the air against a hostile land target. Its range, maneuverability, all weather capability, etc. are expected to contribute to this end. Insofar as dual-use technology products are concerned, they have little applicability to key weapons functions, i.e., the cannon,

* See Volume II of this series for a review of the technical problems connected with the application of civil versions of INS to maritime, air and land vehicle navigation.

rockets, air-to-surface missiles and bombs which make up the weapons suite. It is possible, however, that some civil products could be exploited to enhance the target acquisition and fire control requirements of the aircraft. Modular fire control and attack radars can be installed which carry out search, acquisition and lock-on functions against ground targets. They operate in the I (8-10 GHZ) and J (10-20 GHZ) bands with peak power ranging from 70-200 kw or more. These parameters are in line with the radar equipments described in paragraph

(c) of Item 1510A of the CCL which require a validated license for export. Both Thomson-CSF of France and Smith Industries of the United Kingdom produce a very broad range of these equipments.

In addition to radar fire control, laser rangefinders are also used for air-to-ground ranging. The Thomson-CSF TAV-38 uses a neodymium laser with an output wavelength of 1.06 microns. It is possible that the Nd lasers described in paragraph (i) of (f) of CCL Item 1522A could be utilized in producing this system. As in the case of the radar, however, it is unlikely that these products, acquired through commercial channels could be modified for military use by any LDC other than one with considerable experience in military airborne electronics. Even were an LDC to produce a modular fire control system, it would not be on a par with the fully integrated systems provided in retrofit packages by several European manufacturers which can be installed in a variety of attack aircraft. Perhaps the best example of this is the Thomson-CSF VE 110 Head-up Display (HUD) which provides to the pilot flight, target and aiming information as well as navigation and all-weather landing data. The computations involve solid-state, integrated circuitry and the information is displayed on a cathode-ray tube (CRT).

- Electronic Warfare. Equipment which can detect when an aircraft is illuminated by hostile radar, or can jam such signals is available in internal installations or in pods. Such equipment would be essential for an aircraft to function in a reasonably sophisticated air defense environment. There are receivers and transmitters available as civil products which might be adapted to this requirement, but the same caveats would apply to their exploitation as indicated for other elements of the aircraft's electronics suite. In EW as in the other areas, the principal problem for an LDC attempting to exploit dual-use technology products acquired "off-the-shelf" would be the complications of signal processing and display. It would probably be possible for an LDC to import digital equipment including microprocessors and also the cathode-ray tubes commonly used in aircraft to display systems output. It would be much more difficult to provide the essential software application modules and then join these products together into equipment which would meet military requirements. This would be beyond the capabilities of all but a few LDCs.
- Helicopter Electronics. The major electronics emphasis in helicopter development has been in providing all weather target acquisition and fire control equipment. For example, the new Hughes AH 64 will provide a night vision system, FLIR, laser rangefinders and target designation systems, stabilized sights and a fire control computer. The same problems which an LDC would encounter in adapting civil products to upgrading of the electronics of fixed wing aircraft would pertain to helicopter retrofit. As indicated previously there are any number of helicopters sold in Europe, the U.S. and elsewhere for civilian use which could be converted to a ground attack role. Their effectiveness would depend in great measure on their weapons but even more on the electronics systems which control them.

TANKSRationale

The advent of precision guided munitions (PGM) and the experiences of the 1973 war in the Middle East have caused many specialists to believe that tanks no longer will play decisive roles in land battles. This issue is still being debated with regard to the NATO-Warsaw Pact balance in Europe but it is not likely to change the importance which most LDCs attach to the possession of armored vehicles. Of these, the main battle tank occupies the principal place and continues to be viewed by the ground forces of many LDCs as a major indicator of their combat effectiveness. Some ideas of the size of tank inventories throughout the world can be seen in this table of U.S. tank allocations in selected LDCs:

	<u>M 47</u>	<u>M 48</u>	<u>M 60</u>
Brazil	680		
Israel	200	650	810
Pakistan	200	100	200
South Africa	104		
South Korea	920	640	60
Taiwan	1620	380	
Yugoslavia	300		60

Two hundred of the U.S. M 60 tanks were also built under license in Italy. The figures given above for the M 47 and M 48 probably do not reflect accurately the number of these American tanks which are in the hands of LDCs or available through dealers since hundreds more of these series were transferred to NATO countries in the '50s and have since been replaced by new models such as the West German LEOPARD I. The Soviet contribution to the tank inventories of the LDCs has not been insignificant. Between 1948 and 1963 over 30,000 T 54/55s were built and many were transferred to LDCs. The Peoples Republic of China produced similar models as T 59s and quantities of these tanks were sent to Pakistan by the PRC. The T 62 came next and has been made available to LDCs such as Egypt, India, Iraq,

Libya, Syria and North Korea (where it is in licensed production). The newest Soviet tank in production, the T 72, is entering the forces of the Warsaw Pact and is also being transferred to LDCs. India may produce them under license and they have been seen in Algeria. Great Britain has also played an important role in proliferating tanks among LDCs. It exported over 3000 of its CENTURIONS. Moreover, its Vickers Main Battle Tank was designed for export and is also in licensed production in India as the VIJAYANTA. The Iranian Government had placed an order for 1200 of a special version of the newest British tank, the CHIEFTAIN. Because of recent events in Iran, the disposition of models now in production has not yet been clarified although Great Britain is trying to find markets for them. While a smaller number of the French main battle tank, the AMX 30, has been exported and some have been produced under license (Argentina began in 1969). Thus, it can be seen that tanks occupy a major position in the ground forces of developing countries and will probably continue to do so for some time. For this reason, marked improvements in the combat effectiveness of the tanks on one side or another of an LDC confrontation could prove destabilizing.

Costs are a key factor for LDCs in acquiring, maintaining and upgrading tanks. The unit production costs of the U.S. M 60 A1 in 1978 were \$624,687.* The Swiss, in considering costs they will face in proceeding with the development of their new tank, NKPz, determined that their own program would cost them SFr 4.6 million per tank. If instead they purchased the West German LEOPARD II tank, their costs would be SFr 3.5 million.** Even a stripped down version of the new TAM tank developed by the West German firm Marder for Argentina could cost DM 1.5 million while a more fully equipped model could go as high as DM 2.5 million.+ For this reason most LDCs have preferred to upgrade their tank inventories by purchasing new reconditioned and retrofitted vehicles. Vickers offers a program for the complete rebuilding of CENTURIONS done at its own factories or in the LDC. Even this approach is not inexpensive; an independent arms dealer offered reconditioned M 48 A5 tanks in 1977 at a cost of \$500,000 per tank.++ Thus, many LDCs have

* Arsenal of Democracy, by Tom Gervasi, New York, The Grove Press, 1978, p. 138.

** International Defense Review, July 1979, p. 1082.

+ Ibid., March 1979, p. 414.

++ Gervasi, Tom, op.cit. p. 198.

approached upgrading at a slower pace by purchasing modular components which can provide important improvements but at lower cost. There are many firms in the United States and in Europe which produce such modular components for virtually all of the types of tanks likely to be found in LDC parks beginning with the Soviet T 54, the American M 47 and the British CENTURION up through more recent models.

Upgrading Trends

Because of the appearance of new anti-tank capabilities and the development of new tanks over time, LDCs, as well as the industrialized countries have sought to improve existing tanks. Discussed below are recent trends in upgrading and the methods used to make improvements.

- Improvements in Speed, Mobility, Range and Navigation. To achieve increased speed, greater mobility and longer range it is necessary to improve the performance of the propulsion system and this has been the basis for most of the retrofit programs undertaken on vintage tanks. The Vickers retrofit package noted above for the CENTURION involves substituting a GM V-12 diesel engine and David Brown TN 12 gearbox. The rebuilding program of Spain's 400 M 47 tanks by Chrysler Espana includes installation of Continental AVDS 1790A2 750-hp diesel engines. Engine and transmission improvements will continue to appear in new tanks and figure in retrofits. The new U.S. main battle tank, XM1, will be powered by an AVCO-Lycoming AGT turbine of 1500-hp, but there is no consensus among specialists that gas turbines are superior to diesels for tank applications. For example, Rolls-Royce Motors have developed a 1500-hp CV 12 diesel which they hope will be selected for the new British MBT80. Teledyne Continental Motors is developing a 1500-hp diesel AVCR-1360 which could still be used to power the XM-1.

In operations in which tanks will maneuver for long distances over unfamiliar terrain, as is often the case in desert warfare, it is important they be equipped with a land navigation system which is fully independent. This requirement is met by inertial navigation systems (INS).* Israeli Aircraft Industries markets an INS for use by ground strike forces called the T-LANS which claims the ability to navigate a vehicle equipped with it to within 125 meters of target after a fifty kilometer trip with an azimuth accuracy of 2mRad.

- Upgrade Armor, Achieve Lower Silhouette. These are continuous functions in new tank design. Typical of the stronger armor available is the British Chobham laminated armor which was to have been used on the SHIR, Iranian export version of the CHIEFTAIN, and may be used on the new Swiss tank and on the British Main Battle Tank (MBT/80) now in development. Low silhouettes are normally achievable only in the design and development of new tanks. The new Israeli tank MERKAVA takes its low silhouette and engine location from the Swedish S Tank developed in 1967, as does the Marder TAM. In retrofit programs, it is not uncommon to achieve better armor protection by upgrading the turret cupolas.
- Improve Firepower. Replacement of the original gun with new, improved main guns has been, along with the installation of new engines, one of the most common forms of upgrading for main battle tanks. The M 47-48 90-mm guns were replaced by the 105-mm as were the 100-mm guns of those T 55s in the inventories of non-Warsaw Pact countries such as Yugoslavia. New Western tanks including the U.S. XM-1 will be equipped with 120-mm guns, either the Rheinmetall smooth bore gun or the British rifled

* See Volume II of this series for treatment of the technical issues involved in INS applications to tanks.

high-velocity gun. Soviet tanks have followed the same pattern as the 115-mm smooth bore gun in the T 62 was succeeded by a 125-mm smooth bore gun in the T 72. Improvements in ammunition of the armor-piercing variety have also improved fire-power considerably.

- Increased Accuracy. As in the case of military aircraft, there are a variety of individual systems which contribute to the increased accuracy of a tank's main gun. These will be discussed individually and examined for the possibility of utilizing civil products to perform their functions. At the same time, it should be noted that tank specialists have followed the lead of aircraft electronics design in developing fully integrated fire control systems. Managed by a central computer, generally a microprocessor, the integrated systems incorporate all of the data which bear on firing the main gun to insure "first round kill." Figure 2 illustrates the integrated fire control system used in the TAM-4, a tank under development by the Marder firm in West Germany for Argentina.* Integrated fire control systems of this kind are also produced by other countries and can be utilized in retrofit of existing tanks.

The integrated fire control system shown in Figure 2 for the Marder TAM tank is similar to fire control systems developed by Hughes' (Integrated Tank Fire Control Systems) for the M 60 tank and manufactured by European licensees for use with the LEOPARD Mk 1. British Marconi has also developed an integrated system for tank fire control. It is the SFCS 600, which uses a microprocessor to store information, and obtains target range from a laser range finder, and has been used to upgrade tanks of all vintages, i.e., M 47/48, T 54/55, CENTURION, etc. It is possible, however, to improve accuracy by modular upgrading without resorting to the

* International Defense Review, March 1979, p. 413.

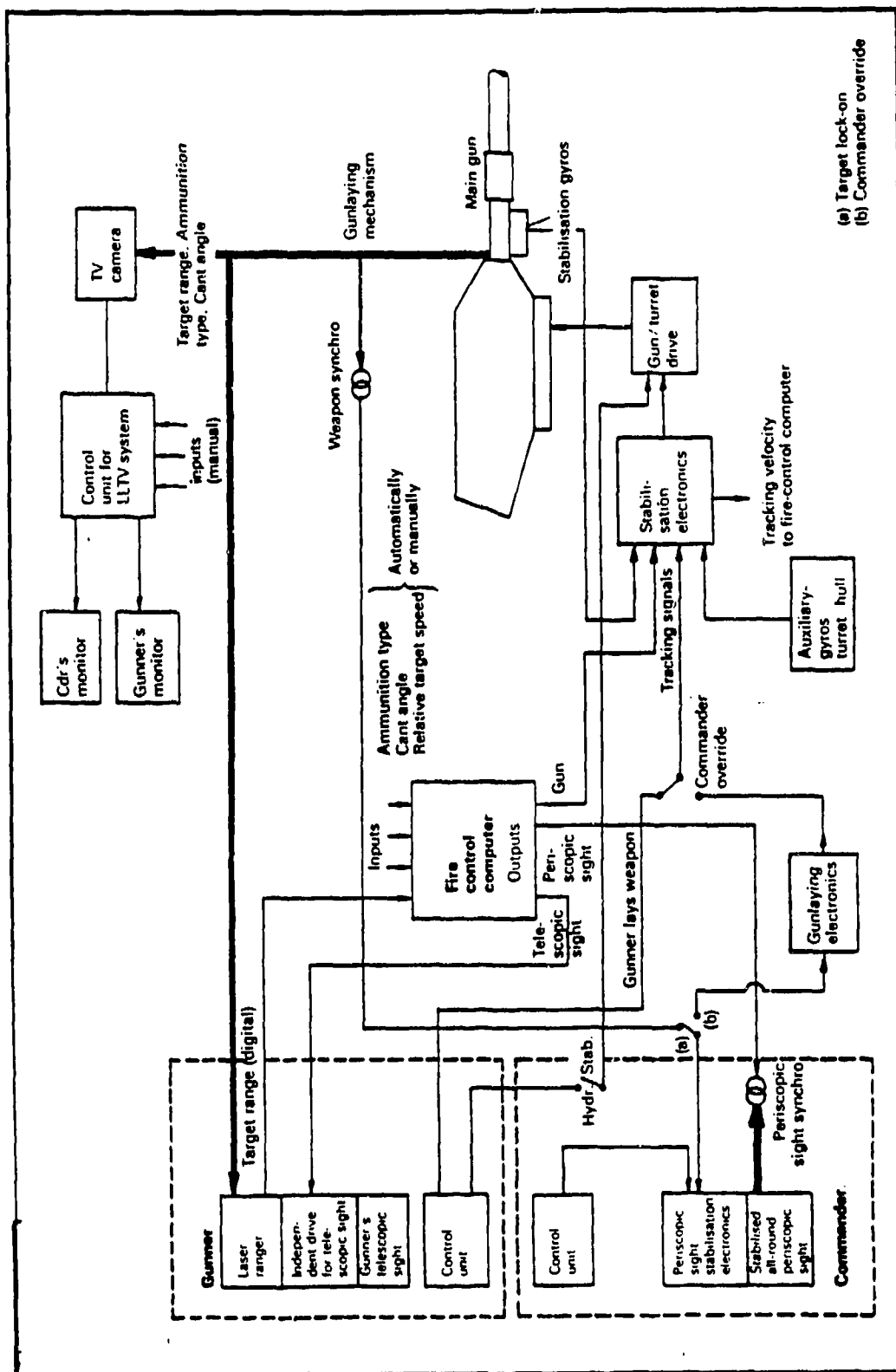


Figure 2. TAM-4 Integrated Fire Control System

installation of an integrated system. For example, laser range finders can be used independently instead of the coaxially mounted machine gun for ranging. Such equipment is made in a variety of countries and is simple to install. (See, for example, the Yugoslav T-LMD 2 tank laser installed in T 55s and T 62s, the French TCV 30 which is also suitable for use with the T 54 and T 55 series and the AVIMO LV2 laser range finder now manufactured by the Singapore subsidiary of AVIMO Ltd). In their upgrading of the CENTURIONS in their possession, the Swedes developed a laser range finder to replace the optical sight thus combining a laser sight with range finder. To provide all weather capabilities and night vision, various devices are used. They include infrared systems, image intensifiers, and low light-level television. All can be applied independently to tanks; the Thomson-CSF TMV 562 LLLTV device, for example, can be installed in the M 48, M 60, T 55, T 62, or CENTURION.

Applicability of Dual-Use Technology Products to Tank Upgrade Requirements

In considering the several trends in tank upgrading described above, it appears there are primarily two areas in which civil products could be utilized. They are propulsion systems and devices to improve weapons accuracy at night and in all weather or battlefield conditions (fog, smoke, etc.).

Propulsion Systems. There are numerous manufacturers of diesel and gas turbine systems in the United States, Europe and Japan who have produced engines for use in armored vehicles. A partial list of foreign firms follows.

AC8WC122

Austria	- Steyrwerk	Israel	- Dodge (license)
Belgium	- Chrysler (subsidiary)	Italy	- Fiat
Brazil	- Mercedes-Benz	Japan	- Mitsubishi
France	- Hispani-Suiza, SOFAM, Peugeot	Netherlands	- DAF
West Germany	- Motor-Turbinen- Union (MTU)	Sweden	- Volvo-Penta
		Switzerland	- MOWAG, Saurer
		United Kingdom	- Rolls- Royce, Leland

Not all of these firms produce engines capable of powering heavy tanks which require in excess of 500 horsepower. In this area the Americans, Germans and British lead although Japan, Switzerland, Sweden and France follow closely. In any case, engines designed for armored vehicles have special characteristics. They emphasize considerations such as low heat emissions to limit battlefield detection. At the same time, however, these same manufacturers, including those who can achieve the horsepowers needed for heavy tank power plants, also produce civil engines for heavy duty use in horsepower ranges which would be compatible with tank requirements. For example, Teledyne Continental Motors produces the AVDs-1970 Diesel at 750-hp for the M 60 tank. It also makes the TCMD-750, a commercial version used in ore moving equipment. The Rolls-Royce commercial line of CV diesels could also be used in armored vehicles. Because of the number of producers in the world, and the fact that propulsion systems capable of providing the necessary power to-weight ratio can be obtained commercially (they are not listed on the U.S. Commodity Control List (CCL), it should not be difficult for LDCs to acquire them. Transmissions required for heavy tanks are another matter. The high mobility and maneuverability of a main battle tank places very heavy demands on the transmission systems. In lighter armored vehicles, such as the Brazilian CASCAVEL, it might still be possible (although not preferable) to rely on manual transmissions, but this has not been the case for some time with heavy tanks. (The AMX 30 is one of the last Western tanks designed with a mechanical transmission). Tanks now employ various hydraulic systems which are specially designed for tanks. Also, unlike the engines, there

is an even smaller number of firms in the world concentrating on the design and production of tank transmissions. This includes Detroit Diesel Allison Division of General Motors (at present the sole maker of tank transmissions in the U.S.), David Brown in the United Kingdom (designers and producers of the new TN 37) and Renk AG of Augsburg, West Germany (furnishes transmissions for the new LEOPARD tank, the Marder armored vehicles including the TAM tank, armored tank destroyers, etc.). Many LDCs could obtain or in some cases a few could even manufacture indigenously diesel engines which meet requirements for tank propulsion. Almost none, and this includes Israel, would wish to make the very considerable investment in manufacturing capability it would take to attempt production of highly specialized tank transmissions. How many would actually succeed if forced to take this step is open to question. Importing these specialized transmissions might be difficult since they are most probably covered under paragraph (g) of Category VII (Tanks and Military Vehicles) of the ITAR which refers to "All specifically designed components" for tanks, etc. Tank transmissions are certainly of "special design." This is not to say, however, that an LDC such as Israel, India or perhaps even Brazil, might not be able to import and then modify heavy duty transmissions used for large construction type vehicles. A resolution of this question would require additional research.

Devices to Provide All-Weather Accuracy. Laser range finders used in tanks are either neodymium: YAG or neodymium: GLASS lasers with output wavelengths of 1.06 microns. As range finder systems they would be on the Munitions List, but the lasers themselves could be purchased commercially, assuming the power demands of the military application could be met. See CCL Item 1522A, paragraph i (f) (1) and (2). Apart from Israel, India, Yugoslavia and Singapore, it is not known which among the LDCs would be able to build lasers into a device capable of converting into distance to a target the time intervals between the emission of a laser pulse and its reception after reflection from a target. Such range data would have to be displayed and then integrated by the gunner into ballistic computations or in a somewhat more sophisticated system would be produced in digital form for passing to a fire control computer. The latter approach has been adopted by most of the current applications of laser range

Austria	- Steyrwerk	Israel	- Dodge (license)
Belgium	- Chrysler (subsidiary)	Italy	- Fiat
Brazil	- Mercedes-Benz	Japan	- Mitsubishi
France	- Hispani-Suiza, SOFAM, Peugeot	Netherlands	- DAF
West Germany	- Motor-Turbinen- Union (MTU)	Sweden	- Volvo-Penta
		Switzerland	- MOWAG, Saurer
		United Kingdom	- Rolls- Royce, Leland

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finders. For example, the Italian VAQ-3 by Selenia integrates its laser range finder with a fire control computer. This system is used on the LEOPARD Mk 1 tank. Thus, for an LDC to produce an effective laser range finder would require not only the manufacturing technique necessary to incorporate the laser into the range finder device, but also possess the microprocessor technology applied to construction of fire control computers.

For night vision enhancement, advanced devices such as low-light level TV are employed (the older, "active" image converters requiring IR illumination, i.e., sniper-scope, etc., are easily obtainable). The Thomson-CSF system TMV 562 (see page 46 for its use in tank retrofit) uses a super nocticon silicon tube of a type which could be obtained commercially. Its export from the United States would require a validated license per Item 1555A of the CCL. Manufacture of the entire system for tank application, while no problem for countries with developed electronics industries, could be difficult for many LDCs.

Another device for enhancing vision at night, in poor weather or adverse battlefield conditions is the thermal imaging system. Sometimes known as forward looking infrared (FLIR) and in increasing use in modern aircraft, this infrared thermal imager enables a tank crew to "see" in total darkness. Its most important advantage is its lack of radiation emissions which improves tank security. Texas Instrument Co., and the Hughes Aircraft Co., have both been active in developing thermal imaging in the U.S. and Hughes has developed systems specifically designed for tanks. While the U.S. has pioneered this technology, it is also available in Europe. For example, a device (RZ 1001) produced by Eltro GmbH of West Germany is applicable to either aircraft or armored vehicles. There are civil applications of these devices, primarily for use in police or commercial security service applications. Presumably it would be possible for an LDC to utilize "off-the-shelf" equipment designed for intruder identification purposes in a tank application. Such products are manufactured in the U.S., the United Kingdom, France and Sweden. Detection equipment using infrared radiation for civil purposes could be exported from the U.S. with validated license under Item 1502A of the CCL (there are some products which are excepted but for many applications they might not be of military quality). If "off-the-shelf" devices for civil use

did not satisfy an LDC who wished to apply the device to tank operations, consideration might be given to importing components to permit production of the device. While Mercury Cadmium Telluride FIR detectors would be available commercially, the problems of array design, optics integration, cryogenic cooling, etc., all essential to thermal imaging systems production, are such that only an advanced LDC would probably attempt indigenous manufacture.

It would appear then that LDCs might be able to acquire civil products or components which if employed in discrete fashion and appropriately modified for installation, could provide some upgrade of main gun accuracy and improvement in visibility. None of these adaptations would be as effective as those manufactured according to military specifications and there is some question about the capabilities of most LDCs to accomplish such adaptations. Furthermore, the degree of upgrade might be minimal in comparison with that provided by more recent fire control and night vision systems which are increasingly integrated under computer control as noted on page 44, and in descriptions of other fire control systems. Some of the latter, such as the SFCS 600, are specifically designed to upgrade vintage tanks of the kind which would probably still be in LDC inventories. Nonetheless, with the exception of Israel, India, Yugoslavia and perhaps a few of the other most advanced LDCs, construction of an integrated, microprocessor-controlled fire control system would be beyond their technical reach. At the same time, any tank upgrading an LDC might hope to achieve by employing individual components adapted from civil products would probably be inadequate against any tank which had received an integrated system.

FAST ATTACK CRAFT/MISSILES (FAC/M)Rationale

The value of small combatants for coastal patrol and interdiction has been understood for many years by the navies of large and small powers. Emphasis on their use varied over time, however, and in many cases the larger, more costly, and possibly more prestigious vessels were preferred. The sinking of the "Eilat" in 1967 by a Soviet FAC/M manned by the Egyptians caused these attitudes to change and the years since 1967 have seen the development of a wide variety of FAC/Ms and their incorporation into the naval forces of many LDCs. The FAC/M is a natural sea weapon for an LDC for many reasons. It is not as costly as a larger class combatant (a tenth of the cost of a destroyer)* and despite their smaller size (under 400 tons displacement for the most part) they may be much faster and can incorporate the firepower of larger ships. Their striking power is made possible by the development of anti-ship missiles which are used most effectively in connection with lightweight, computerized fire control systems. In the hands of LDCs situated in restricted waters such as the Mediterranean, or at international maritime "choke points", they could inflict heavy damage on the naval forces of other LDCs and hence be destabilizing in a purely local LDC context. More important, unlike the other systems studied, they could impact on regional confrontations in a way which could have an inhibiting effect on actions by the naval forces of states much larger than themselves including possibly those of the superpowers.

Availability

The USSR continues to build OSA I and II classes and has transferred over 60 of them to LDCs. While the older KOMAR class has been discontinued, some LDCs such as Egypt, and North Korea still retain them in their fleets. It is possible that the Soviet Union has decided to replace OSAs with hydrofoil FAC/Ms. The SARANCHA class hydrofoil

* Arthur Davidson Baker III, "Small Combatants", United States Naval Institute Proceedings, May 1972, p. 242.

has appeared with Soviet naval forces but to date none has apparently been transferred to an LDC. After the USSR, the largest builders of FAC/Ms are West European yards. They in turn export a large proportion of their output to LDCs.

The United Kingdom leads in the design and production of patrol craft, gun-boats and FAC/Ms for export through the efforts of its two major small combatant yards, Brooke Marine and Vosper-Thornycraft. The six Vosper 121-ft FAC/Ms sold to Venezuela in the mid-70s provide an excellent example of the multinational manner in which FAC/Ms are outfitted: Franco-Italian OTOMAT missiles, Italian OTO Melara guns and radar (SELENIA), with propulsion systems by MTU of West Germany. Next to Great Britain, France and West Germany are the most aggressive export FAC/Ms. Collaboration between the countries has resulted in the development and construction of the well known La Combattante II class (as Type 148, a total of 20 were built in France for West Germany between 1972 and 1975, as the SA'AR class, 12 were built for Israel, while others have been sold to LDCs such as Malaysia, Argentina and Singapore). The West Germans then designed the Type 143, a much larger vessel, for their own use and for exporters of (Nigeria ordered three). This class is built in West German yards. The combination of the French EXOCET surface-to-surface missile and German propulsion systems makes for an extremely effective combatant. Of special interest, however, is the "La Combattante" class of twelve FAC/Ms constructed for Iran. Built at the Construction de Mecanique, Normandie, shipyards in France, these vessels are outfitted with MTU diesels, four U.S. HARPOON missiles, an OTO Melara 76-mm gun and a 40-mm Bofors gun. Their fire control is from the Hollandse Signaalapparaten. Italy follows France and Germany in building FAC/Ms. It has several naval shipbuilding yards and is actively engaged in export to LDCs. For example, Thailand commissioned three FAC/Ms of 270 tons displacement, armed with EXOCET missiles from the C. N. Breda yards. Norway has also specialized in the design and construction of FAC/Ms equipped with Norwegian-built PENGUIN missiles. A large number of orders for Norwegian FAC/Ms comes from Sweden but Norway is also involved in the LDC market.

LDC capabilities for FAC/M production are growing. Israel produces the RESHEF, which at 415 tons displacement and 190 feet overall length, is one of the largest FAC/Ms in Western navies, as well as the DVORA, one of the world's smallest missile attack craft (75 feet). Singapore is rapidly developing a reputation for competence in the construction of small combatants. It produces a FAC/M designed by the West German yards Luerksen Werft plus FACs of Vosper design. Singapore's future impact on small combatant construction can be seen in its development of a new, small (62 metres) corvette designed specifically for export to Far Eastern and Middle East navies. Yugoslavia has also designed and built FAC/Ms for its own forces (Type 121). In addition, it built several FACs/torpedo of the Soviet SHERSHEN class and 14 patrol boats of the old U.S. Higgins class of which several were transferred to the Sudan. Several other LDCs are engaged in building modern FAC/Ms under license. They include Argentina (Luerksen Werft design), Egypt ("October 6" class, KOMAR design), North Korea (Soviet designs), South Korea (Tacom PSMM 5 designs),* South Africa (Israeli RESHEF design), and Taiwan (Tacoma PSSM design).**

It is recognized that the FAC/Ms described above, including the most recent designs, may be replaced to some degree by hydrofoil missile-firing vessels. Many of the Western countries discussed above have had extensive hydrofoil design and construction programs underway for some time. So far, only Singapore and Israel (assuming Israel is licensed to build the U.S. hydrofoil FLAGSTAFF) have done so. Because of the construction problems inherent in hydrofoils, and continuing disagreement over the difficulties they may pose in handling in a missile-attack role, this paper will not treat hydrofoils as they might someday relate to LDCs.+

* South Korea has also constructed other patrol craft of indigenous design including two 120 ton vessels equipped with EXOCET missiles; thus South Korea should be able to construct larger FAC/Ms.

** After building one of this class, Taiwan cancelled the agreement. According to Jane's Fighting Ships, 1978-79, Taiwan will build FAC/Ms of its own design.

+ Rodney P. Rempt, "Employment Plans for U.S. Navy PHMs," United States Naval Institute Proceedings, June 1976, p. 93.

Upgrading Trends

As in the case of other weapons systems, improvements through modular upgrading to FAC/Ms already in the naval forces is a common practice in all countries and is not restricted to LDCs. The improvements generally sought are increased speed, greater firepower and better accuracy through improved fire control.

Increased Speed. Here again, as in the case of aircraft and armored vehicles, increased speed is obtained primarily through the installation of newer, more powerful engines. Better hull design is an important factor but normally achievable only when developing new classes. The FAC/Ms referred to above generally require from 12,000 to 15,000 shaft horsepower for effective operations. Such power levels are normally made possible by using three or four diesel engines. A majority of FAC/Ms in LDC hands including some of those produced by the Vosper affiliate in Singapore are outfitted with diesels manufactured by the West German firm Motoren-Turbinen-Union (MTU). There are, however, a number of other manufacturers of high speed marine diesels in Europe (SACM - France, PAXMAN - United Kingdom, GMT - Italy). While all diesel systems remain an important power source, builders are turning increasingly to gas turbines which are capable of very high speeds. For example, the British Vosper FAC/M SUSA class vessels exported to Libya are powered by three Bristol Siddeley "Proteus" gas turbines as are the Yugoslav indigenously designed and built FAC/Ms noted above. In addition to the British firms, General Electric, AVCO-Lycoming and Pratt and Whitney in the United States also produce marine gas turbines. For operations over longer ranges (many FAC/Ms such as the Israeli RESHEF are capable of this) a combination of gas turbines for the high speeds needed in combat operations and diesels for economical cruising may some day be preferred. Upgrading of propulsion systems can utilize any one of the systems described above but to date diesels have been most commonly chosen for FAC/Ms. This was the case when Egypt substituted MTU diesels for Soviet Diesels in its OSA class and in its "October 6" class FAC/Ms.

Greater Firepower. Obtainable by upgrading ordnance. The French EXOCET, the Franco-Italian OTOMAT, the Norwegian PENGUIN, the Israeli GABRIEL, and the U.S. HARPOON are all surface-to-surface anti-ship missiles of varying characteristics which are found alone or in combination on all of the FAC/Ms covered in this paper except those built by the USSR or under Soviet license by other states. The best known Soviet missile of this type is the SSN 2 (STYX), which is still being supplied to LDCs and Warsaw Pact nations with the OSA class FAC/Ms in their fleets. Other weapons upgrading could derive from changes in guns from 20-mm to 30-mm or from 40-mm to 57-mm, etc.

Fire Control/Combat Management Systems. Larger naval combatants have all had for some time extensive combat control systems which integrate tactical data, communications, navigation, electronic warfare measures, target detection and tracking and weapons firing. Integration and display of this information is handled through computers such as the Ferranti 1600E. Smaller, missile-firing craft have not enjoyed this flexibility in the past and upgrading has often been accomplished one component at a time (as in the case of the Egyptians who replaced their Soviet equipment with Kelvin Hughes 1006 surveillance radars and Decca navigation radars on the OSA I class vessels). Recently, however, there have been efforts to develop fully integrated command and fire control systems for FAC/Ms. Systems of this kind are made in West Germany for its Type 143 and Type 148 class boats (possessed by several LDCs). Hollandse Signaalapparaten also offers a Mini-Combat System for fitting in small craft. It comes in several modes depending on the number and type of weapons to be controlled. Figure 3 below describes a Swedish fire control system for small combatants built by Phillips of Sweden in conjunction with Saab-Scania.*

* Jane's Weapons Systems, 1979-80, p. 254.

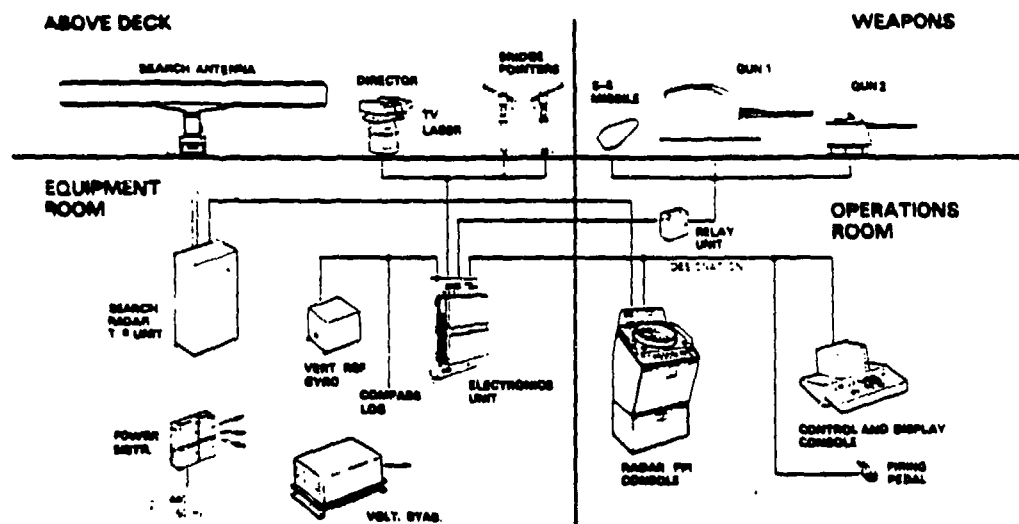


Figure 3. 9 LV 100 Fire Control System
Block Diagram

The key to accuracy, of course, is the guidance and homing systems provided by the anti-ship missiles which are, of course, the decisive element of the vessel's weapons suite. A cursory review of these systems and their functions in the EXOCET, OTOMAT, PENGUIN and HARPOON missiles reflect this.

EXOCET - Guidance carried out through a pre-programmed flight path based on data on the target from a fire control computer. In this phase of its flight the missile uses a twin-gyro inertial navigation system and a radio-altimeter to keep it at low altitudes. It homes on its target by means of a radar homing head.

OTTOMAT - Similar to EXOCET but containing a strapped down inertial guidance system, an on-board microprocessor, and dual homing heads, one infrared and the other active radar. OTTOMAT can be utilized with any target acquisition radar and fire control system.

PENGUIN - Same general approach as for EXOCET and OTOMAT. Target data from the fire control computer is fed to the missile whose inertial guidance system is thus programmed. The homing head contains an infrared detector system which searches for and then directs the missile on to target.

HARPOON - A large missile but still capable of being operated from FAC/Ms (the Israelis will have it on their RESHEF class). HARPOON obtains target data from normal shipboard systems which are fed to its on-board digital computer. It is then launched by boosters into a ballistic trajectory after which it descends into cruise altitude. Once the missile is launched no further data is required from the ship. HARPOON has an active radar homing head which can lock on to a target even if the latter is taking evasive action.

STYX - Early models involved radio command guidance for the cruise phase plus an infrared homing device. Changes may have occurred in recent models.

For all of the missiles described above, target data can be obtained via digital links from other ships, aircraft or shore installations or from the launching ship's own optical or radar systems. Search radars generally operate in the I/J band with 100 kw output. The tracking radars operate in the upper J band at 65 kw output. These radars and optical systems are often augmented by IR or LLTV trackers and by laser range finders. These later systems enhance the FAC/Ms' all-weather and night operations capabilities.

Applicability of Dual-Use Technology Products to FAC/M Development or Upgrading

It is true that the FAC/M represents an ideal solution for LDC naval forces from the point of view of cost-effectiveness; also, it is potentially one of the most

destabilizing weapons systems if used in certain geographic areas. On the other hand, its potential derives from the surface-to-surface, or anti-ship, missiles in its weapons suite. Without them it would be just another patrol craft. Therefore, in considering ways in which LDCs could exploit dual-use technology to develop or upgrade an FAC/M, it is assumed that the LDC has or can obtain the requisite missiles. So far, only Israel has shown a production capability in its design and production of the GABRIEL MK 1 and MK 2 missiles. These performed effectively in the 1973 War and have been exported to several LDCs among them Argentina, South Africa and Taiwan. Consequently, while many LDCs could construct hulls, and possibly use civil products for some of the necessary outfitting, almost none could produce the missile systems to transform the vessel into a FAC/M.

Propulsion Systems. Whether to power a new hull, or upgrade an existing FAC/M, it should be possible for LDCs to import either diesel engines or gas turbines or both. In the case of the turbines, Item 1413A of the CCL stipulates that a validated license is required for engines of 3,500 rated shaft horsepower and above but there is no such requirement for diesel maritime engines designed for use by vessels other than submarines.

Electronics Equipment. As in the case of the attack aircraft there are civil radars which could meet some of the surveillance and target tracking requirements of FAC/Ms. The importation of maritime radars would not be enough since the importing LDC must also have the capability of processing and displaying the data obtained by radar and transmitting the target information acquired to the missiles. This would require considerable experience in the installation and maintenance of naval weapons systems.

ROLE OF FOREIGN SPECIALISTS IN ADAPTING DUAL-USE TECHNOLOGY
PRODUCTS TO WEAPONS SYSTEMS UPGRADING

A constant theme running through this paper is the inability of many LDCs to cope with the problems of civil product modification and systems integration which would be encountered in attempting to exploit such products for weapons systems upgrading. Even for LDCs with a reasonable level of expertise in, and shop facilities for, weapons systems maintenance and overhaul, adaptation of civil products would present special difficulties. For LDCs without such capabilities, adaptation of these products would be impossible except for the simplest, least complicated applications.

There is, however, a way to circumvent these difficulties and that is the use of foreign specialists. This would not be a new pattern. Foreign engineers and technicians generally form part of the sales and servicing agreements entered into by LDCs when they purchase new or entirely rebuilt weapons systems from foreign suppliers. Even in the case of modular upgrading through items such as laser range finders in night vision equipment, it is not unusual for the foreign supplier to provide technical teams to perform the retrofit and train local personnel in its use and in basic maintenance. In theory, this same approach could be used to deal with the adaptation of civil products for weapons systems upgrading. The appropriate dual-use technology products could be imported from either the United States or foreign suppliers, ostensibly for civil use but in reality to serve as substitutes for military products in weapons systems upgrading. Separate arrangements could then be made to secure the services of qualified U.S. or foreign specialists who would make the necessary modifications, then install the modules and integrate them properly with the total system.

This approach has been judged only theoretically valid, at least insofar as the United States is concerned, because it would appear to be a violation of the spirit if not the letter of several sections of the current ITAR dealing with technical assistance (Part 124) or with the "modification of foreign-owned arms" (Part 125). The

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export of civil products for use in military systems would be a subterfuge involving possible violations. For United States' firms to permit LDCs to contract for the services of their specialists to carry out such modifications would appear to be a much clearer violation of the intent of ITAR.

FINDINGS AND CONCLUSIONS

These findings and conclusions are tentative and can only reflect our estimate of current LDC capabilities. More precise judgments on how well LDCs would be served if they applied dual-use technology products to upgrade potentially destabilizing weapons systems will require additional research into the technical considerations underlying such application. The systems studied were:

Surface-to-Surface Missiles
Attack/Ground Support Aircraft
Tanks
Fast Attack Craft/Missiles

We presently believe that:

- The variety and number of suppliers of military systems and modular components throughout the world is such that LDCs wishing to develop or upgrade many of the systems studied could probably purchase the appropriate components or arrange to produce them under license.
- The highly competitive nature of the arms trade is such that the efforts of LDCs to acquire such components would probably be accommodated by one or more suppliers.
- If, for whatever reason, LDCs were unable to conclude sales or coproduction agreements leading to the acquisition of the military components needed for systems development or upgrading, some LDCs could, given appropriate investment decisions and the continued availability of raw and semi-finished materials from abroad, produce some of the required components indigenously both for their own use and for export.

- In circumstances in which LDCs could neither acquire military products for upgrading from foreign suppliers, nor produce them indigenously, there are some dual-use technology products, not normally controlled to LDCs, which might contribute to upgrade programs. The extent of these contributions and their significance in terms of systems performance will vary greatly but may be expected in two principal areas:
 - Propulsion Systems. There are a variety of aircraft, automotive and marine power plants designed for civil use and normally available through commercial channels which could be adapted to military purposes if the recipient countries were capable of making the necessary modifications and installing them. The complexity of these modifications may vary considerably. Transmissions for tank engines may pose special problems, however, because of the unusual demands placed upon them by tank operations and the limited number of firms in the United States and Western countries engaged in their manufacture.
 - Electronic Systems. These electronic systems with counterparts in civilian aircraft (navigation, flight control, radars, etc.) and normally available through commercial channels could be exploited to achieve some level of upgrading for military purposes in the aircraft studied. Electronic systems designed for or associated with weapons management (fire control, ranging, sighting and aiming, guidance, etc.) pose significantly greater difficulties, however, because the civil products which might be exploited for these purposes will not always meet military specifications and will in all cases require a high degree of skill in their modification and installation as elements of an integrated system. This is true

of their application to each of the systems studied (Cruise Missile, Attack/ Ground Support Aircraft, Tanks and Missile-Firing Patrol Boats).

- The modifications required to adapt civil products to military purposes, particularly in the electronics field, demand levels of expertise on the part of concerned LDCs which are not inferior to those required for indigenous production of entire systems or modular components. This would limit the number of LDCs capable of opting for exploitation of dual-use technology products.
- These constraints would not affect those LDCs capable of securing the services of foreign technicians to assist them in adapting civil products to military requirements. (For U.S. persons such activity undertaken without approval might violate provisions of International Traffic in Arms Regulations/ITAR pertaining to foreign technical assistance).
- In any case, the impact on the regional balance of upgrading potentially destabilizing weapons through exploitation of dual-use technology products by a LDC would be essentially proportionate to the degree of sophistication embodied in the weapons systems in use on both sides in a regional confrontation.
- In considering the development of surface-to-surface missiles, the ballistic guided missile presents special difficulties for LDCs. There are dual-use technologies which could be exploited, but their application and integration without foreign assistance would be beyond the capabilities of the LDCs studied except perhaps for India and Israel.*

* See the related study of this series which bears on LDC development of ballistic missiles: Volume III, A Study of the Exploitation of Dual-Use Technologies: South Korea (U), September 1980, classified Confidential.

- The cruise missile may, however, represent a special opportunity for some LDCs to develop a weapons systems capable of destabilizing a regional confrontation because:
 - Airframe requirements can be met in ways which are within the technical competence of many LDCs.
 - At the present time suitable propulsion systems can be acquired commercially.
 - For limited range applications, guidance systems need not be complex.
 - Warheads, utilizing either high explosives or chemical warfare agents, can be devised at minimum levels of efficiency which could nevertheless meet LDC requirements.

Keeping in mind the caveats, which are reflected in the body of this report and in the above findings/conclusions, Table 1 hereto provides an overall summary for the reader's convenience of the potential for LDC's to exploit dual-use technologies in developing or upgrading the four weapon systems studied.

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TABLE 1. ANNOTATED LIST OF DUAL-USE
TECHNOLOGY PRODUCTS

MILITARY SYSTEM	KEY FUNCTION	KEY PRODUCT	DUAL USE	APPROXIMATE # OF COUNTRIES (non-Communist from which available)	ADAPTABILITY OF CIVIL PRODUCTS	REMARKS
SSM						See "Technology List for Observing Possible Indigenous Development/Production of a Surface-to-Surface Missile System by a Less Developed Country (LDC)", August 1979, SAI, Leslie F. Eghart, Jr., and James O. Frankosky.
Cruise Missile	Structure	Airframe	Yes	>10	Easy	On airframe fabrication not difficult for existing aircraft industries.
Cruise Missile	Propulsion	Turbojet Engine	Yes	10	Easy	
	Guidance	LORAN	Yes	>10	Easy	Requires terminal homing.
		Radio Command	Yes	>10	Easy	Adaptable for short range.
		INS	Yes	7	Easy*	Requires terminal homing.
	Storage	Warhead	No	>10	N.A.	
Attack/Ground Support Aircraft	Attack/Ground Support	Fixed Wing A/C	Yes	>10	Varies	Civil Aircraft adaptation easy for certain missions.
		Rotary Wing A/C	Yes	>>10	Easy	Differences between military and civil versions minor.
	Propulsion	Turbojet/turbo-prop, turbo-shaft engines	Yes	10	Easy	
	Flight Control	ILS	Yes	>10	Varies	Ease of upgrading depends on level of upgrading
		Autopilot	Yes	ca 10	Varies	
		Radar	Yes	>10	Varies	
	Navigation	Radio Navigation Systems	Yes	>10	Varies
		INS	Yes	7	Varies
	Communications	Transceivers, UHF, VHF	Yes	>>10	Easy	
	Weapons Management	Target Acquisition	No	ca 10	N.A.	Comparable civil components not always appropriate; systems integration difficult.
		Fire Control	No	ca 10	N.A.	Advanced flight management systems could provide basis for conversion to weapons management in the future.
		Night Vision	Yes	<10	Varies	Civil products such as LLTV, thermal imagers, etc., are used in police applications but their adaptation to military requirements except in simplest form would be difficult.
	Electronic Warfare	Detectors, Jammers	No	ca 10	N.A.	Adaptation of civil receivers and transmitters unlikely.
Tanks	Propulsion	High power diesel, gas turbine engines	Yes	ca 10	Easy	Minor mods can improve military utility.
		Automatic Transmissions	No	<5	N.A.	Might be possible to modify civil heavy duty transmissions but cannot verify
	Weapons Management	See section on Attack A/C above				
FAC/W	Propulsion	Marine diesel, gas turbine engines	Yes	<10	Easy	
	Fire Control	See section on Attack A/C above				

* Adaptation was difficult providing aerial vehicle launching made does not impose high acceleration

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